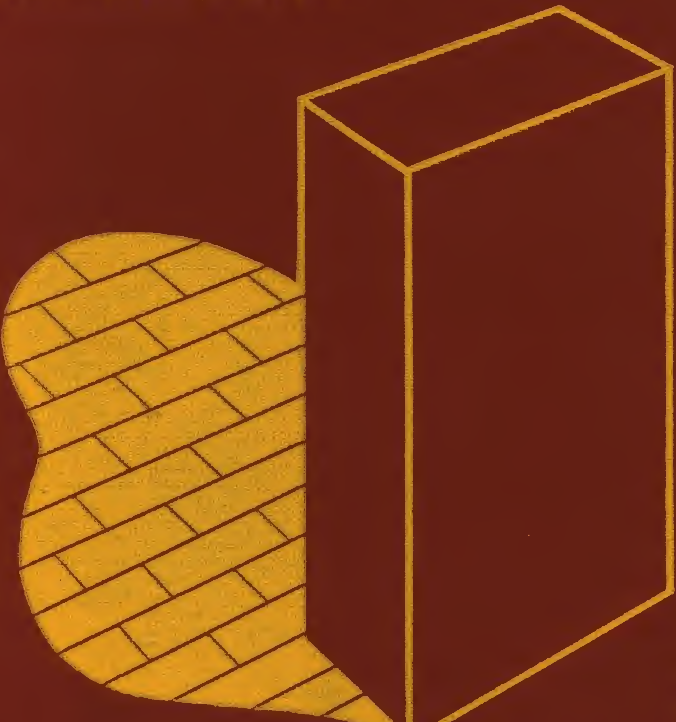
Masonry Simplified

DALZELL-TOWNSEND



TOOLS
MATERIALS · PRACTICE

VOLUME I

Jack Lawlor

MASONRY SIMPLIFIED

Volume I

TOOLS • MATERIALS • PRACTICE

ERECTION OF THIS COMPLEX, MOISTURE-PROOF WALL REQUIRES ADVANCED MASONRY TECHNIQUES
Courtesy of American Builder

MASONRY SIMPLIFIED

Volume I

TOOLS • MATERIALS • PRACTICE

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PREFACE

THIS volume on the fundamentals of masonry practice is a valuable source book for those interested in any phase of masonry work. The information presented has been drawn from a multitude of sources. For many years the authors have been in daily contact with building tradesmen, contractors and builders, architects, and vocational leaders connected with training programs. They have been in close touch with leading manufacturers of building materials. From these intimate associations has developed a real understanding of the problems encountered in masonry practice and the best methods for solving them. It is this vast fund of knowledge and experience the authors have made available in their *Masonry Simplified, Volume I—Tools, Materials, Practice.*

The building activity in this country has been responsible for large numbers of new workers finding employment in the building trades and a substantial share of these have entered the field of masonry. Another large group is represented by those people, farmers for example, who do a certain amount of masonry work themselves, and by beginners and on-the-job trainees. The natural result is a definite need for a book which can offer these people the proper guidance in elementary masonry work.

An outstanding feature of this book is the large number of illustrations which have been prepared to supplement the descriptions in the text. For the most part, they are the pictorial or three-dimensional type since drawings of this nature are easiest to visualize and understand. A sincere effort has been made to avoid the flat, ordinary type of drawing.

A series of questions and answers and review questions at the end of each chapter is a valuable attribute. This section, called "Checking on Your Knowledge," enables the reader to perform a self check on his retention of the material just covered.

Throughout the text emphasis has been placed on the fundamental aspects of masonry. The first three chapters, therefore, are devoted to the study of the cementitious materials used.

The handicap of an inadequate knowledge of blueprint reading has

been recognized and a chapter prepared to assist the reader. The ability to visualize building plans or blueprints is quickly acquired by means of the cleverly conceived and skillfully executed picture-like drawings which aid visualization. This chapter on blueprint reading for the masonry trade is an important contribution to any study of the subject.

Actual practice in building is described in the three chapters given over to the study of unit masonry. The material on the use of concrete block, clay tile, and brick enjoys a unique presentation in that the authors have stressed corner construction and unit planning as the key to properly bonded walls—points which have been omitted in most masonry texts. Once the basic factors involved in wall building have been explained, their principles are described in relation to actual construction. The result is a thorough treatment of the various wall patterns, bonds, joints, tools, and other important considerations involved in unit masonry.

The final chapter describes the building of concrete sidewalks, driveways, floors, and steps. These structures are important and are sometimes difficult to build. However, if the practice recommended in this chapter is followed, no difficulty should be encountered in their construction.

No small debt of gratitude is due Mr. B. E. Ferrell, Jr., for his preparation of the reader-motivating "Questions This Chapter Will Answer for You" and the introduction which appear at the front of each chapter, in addition to his untiring, conscientious editorial work in the organization and preparation of the manuscript.

Masonry Simplified, Volume I—Tools, Materials, Practice cannot be substituted for practical experience in the field. But, in its role as silent instructor, it goes all the way in providing accurate counsel in all phases of elementary masonry work.

THE PUBLISHERS

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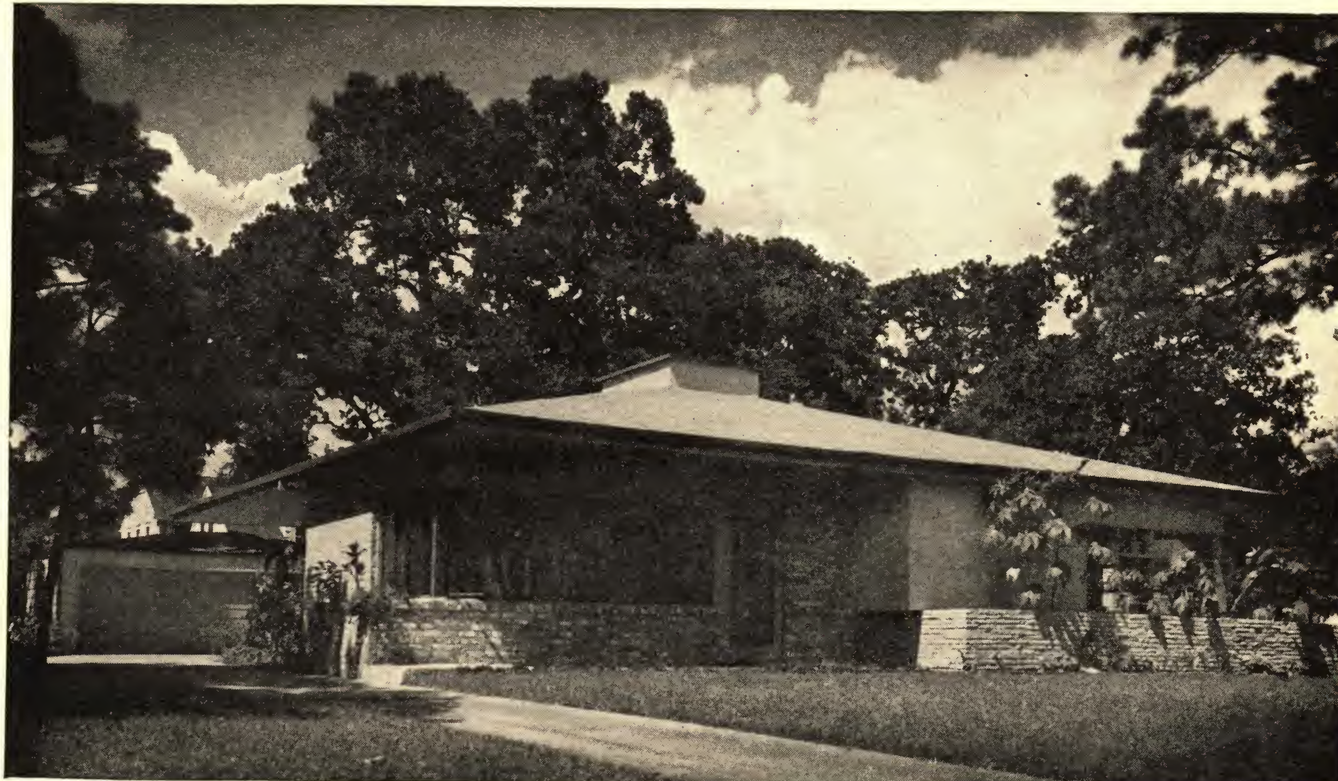

THE CONTEMPORARY HOUSE USUALLY EMBRACES SEVERAL VARIETIES OF MASONRY CONSTRUCTION
Courtesy of American Builder

CHAPTER I

Lime, Its Manufacture and Application[1]

QUESTIONS CHAPTER I WILL ANSWER FOR YOU

1. *What are the steps and processes involved in the average lime manufacturing plant?*
2. *What are the physical and chemical properties and characteristics of lime?*
3. *What tests may be made in order to determine the proper slaking procedure for a particular lime?*
4. *What are some of the many industries in which lime is commonly used?*
5. *What are some of the uses and functions of lime in masonry construction?*

INTRODUCTION TO CHAPTER I

A *good* mason, like any skilled tradesman, has a thorough knowledge of his trade. Moreover, he is always willing to add to his fund of information for he is well aware that "You're never too old to learn." Acquiring new facts relative to the trade makes his work more interesting and fills the mason with the pride that is necessary for good work.

This first chapter contains much information that will be of interest to the experienced mason and an even greater amount of information that the apprentice or inexperienced person will find indispensable. Here is a chapter that discusses the basic substance forming all cementitious materials used in modern masonry construction. Without lime, architecture as we know it today probably would not exist.

You will find that the peoples of early civilizations recognized and used lime. One cannot help but be impressed by the three thousand years of masonry's heritage. You will learn what lime is and about the various types of limestone from which lime is made. You will read a description of lime manufacturing processes from quarry to bag so well illustrated with diagrams and photographs you will feel you have made a personal tour of inspection at the nearest plant. You will learn how to handle the various limes in the processes of their slaking. You will learn the chemical reaction involved in slaking lime—perhaps the answer to a curiosity dating back to your youth when you wondered why the mortar box bubbled and steamed like an angry Vesuvius. You will discover the many commercial uses of lime other than in the manufacture of cementitious materials.

When you have finished this chapter, when you are familiar enough with it so that you can answer the questions that appear at the end of the chapter,

[1] This chapter was developed through the co-operation of Dr. G. J. Fink, Executive Secretary of the Oxychloride Cement Association, Washington, D.C.

you will have acquired the foundation on which to build the skill and knowledge so essential to good masonry practice.

USES OF LIME

For centuries, lime has been used as a masonry material by peoples throughout the world—by the Egyptians in their temples, by the Persians, the Greeks, and the Romans. Recent chemical tests of some of these ancient structures in Egypt, Greece, and Italy show that the mortar was made of mixtures of lime and volcanic ash or of lime and gypsum; in many instances, the mortar is still in excellent condition.

In addition to its early use as a building material, lime was among the first chemicals utilized by man and lime-burning became one of the earliest chemical industries.

Lime is very active chemically. It is caustic in nature and the solution formed when it dissolves in water is highly alkaline. It is the cheapest alkali known and hence is used in very large quantities in those chemical and process industries requiring alkali of this type. Owing to its great chemical activity in other respects, it is widely used as a chemical in practically all industries. It is used in making glass, paper, sugar, rubber and rubber products (both natural and synthetic), iron and steel, pottery, textiles, petroleum, greases, soaps, carbide, bleaching powder (chloride of lime), insecticides, and in many other products. Large tonnages are used for purification and softening of both potable (drinking) and industrial water and for treatment of the waste waters from many industries.

In agriculture it is widely used for neutralizing acid soils and for adding the required quantities of calcium and magnesium to soils deficient in these essential food elements. It is used for making various spraying materials, insecticides, and fungicides such as lime sulphur, bordeaux, and calcium arsenate.

Lime is even more important as a masonry material today than it was in ancient times. The purpose of this chapter is to acquaint the reader with lime insofar as its types and forms, manufacture, properties, and uses and functions are concerned.

WHAT IS LIME?

The name lime has been applied somewhat loosely to at least three chemical types of material, including limestone, quicklime, and

hydrated lime. However, to be exact, this term should be restricted to quicklime and to hydrated lime.

Quicklime. Quicklime is the solid product remaining after limestone has been heated to a high temperature. Therefore, the process of producing lime is described as lime-burning; another term, calcining, means exactly the same. Probably this process is nearly as old as the use of fire, for it is likely that lime was discovered when a prehistoric man lighted a fire on rocks composed of limestone.

Hydrated Lime. When quicklime comes in contact with water, there is a chemical reaction which produces a large amount of heat and sometimes an almost explosive violence. Probably for this reason, the product of burning limestone came to be called quicklime. The material remaining from the action of water on quicklime is called slaked lime or hydrated lime.

Classes and Types of Limestone and Lime. On the basis of origin, the geologic deposits of the carbonates, or limestones, may be separated roughly into two classes: those of organic origin which are the accumulated remains of organisms such as shellfish, mollusks, etc., and which are represented by the fossiliferous stones and corals; and those of chemical or physical origin formed by chemical precipitation or sedimentation such as the stalactites, stalagmites, and the oölitic and pisolitic limestones. Building stone (limestone) is chiefly of the oölitic type.

Certain crystalline, high-calcium limestones, usually containing small quantities of impurities which account for the variety of colors, are called marble. Other pure forms of calcium carbonates are designated by mineralogists as calcite or aragonite, depending upon their crystalline form.

Limestones from which commercial limes are made must be quite pure. Desirable deposits are widely distributed over the earth. The two general types of limestone used for lime manufacture are high-calcium limestones and magnesium or dolomitic limestone. The calcium stones are chemical combinations of calcium oxide (the metal calcium and the gas oxygen) and carbon dioxide. The dolomites contain both calcium and magnesium oxides in approximately equal proportions, combined with carbon dioxide.

Owing to differences in limestone composition, quicklimes are known

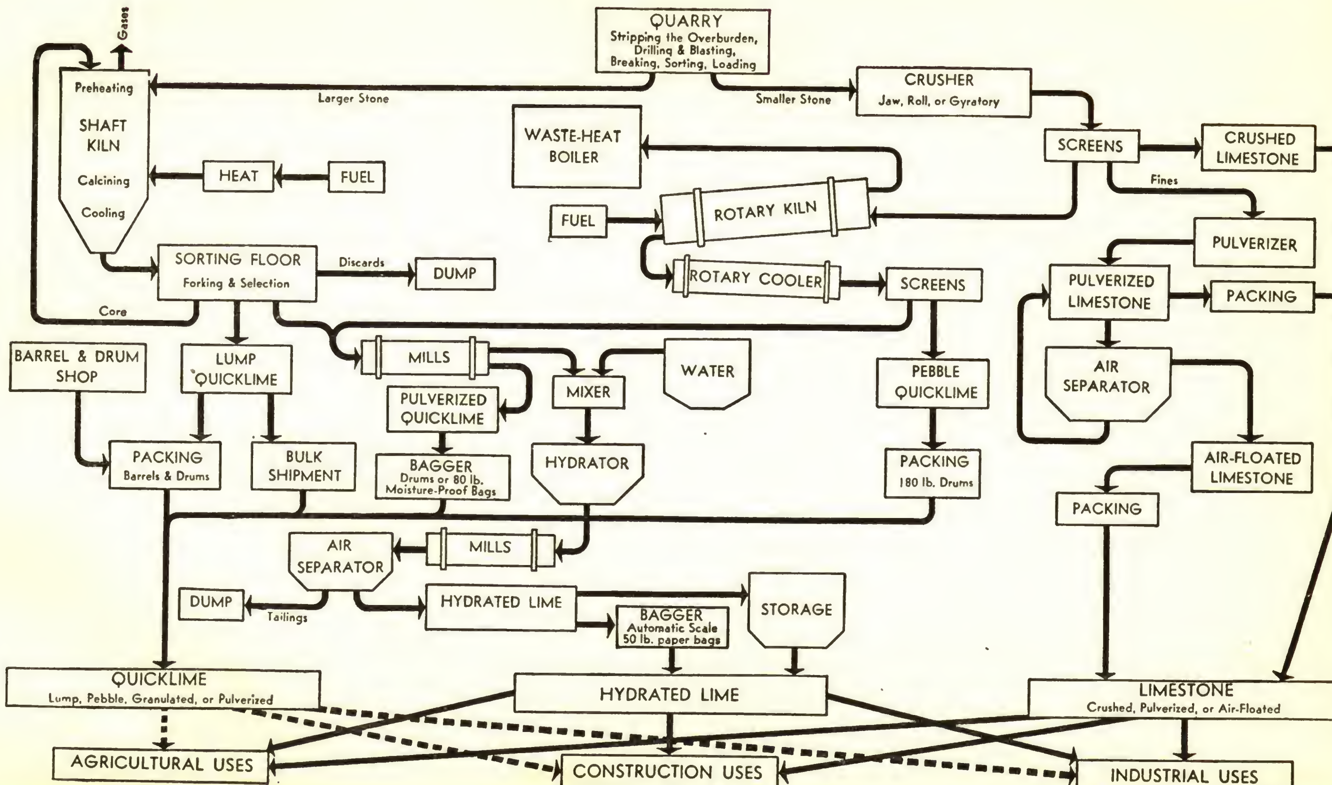

Fig. 1. Flow Sheet of Lime Manufacture

either as high-calcium quicklime or as dolomitic or magnesium quicklime, depending upon the stone from which they are produced. When quicklime is slaked with water, the calcium quicklime yields a high-calcium hydrated lime and the magnesium quicklime yields a magnesium or dolomitic hydrated lime. Usually, the two types of quicklime can be distinguished during slaking by the rate at which they react with water or by the temperature produced. The calcium limes, as a rule, slake more rapidly and produce higher temperatures than do the dolomitic quicklimes. This difference in slaking characteristics is explained by the fact that under ordinary conditions only the calcium oxide of the dolomitic lime reacts with the water. The magnesium constituent reacts not at all, or only partially, with the water. By special processes of slaking or hydration, the magnesium of the dolomitic limes can be made to react with the water, producing what might be called highly hydrated dolomitic limes. The usual type of dolomitic hydrated lime, therefore, should be distinguished from the normal or partially hydrated lime.

LIME MANUFACTURE

Most commercial lime plants produce limestone, quicklime, and hydrated lime.

Limestone products include building stone, ballast, aggregate for concrete, agricultural limestone, and crushed or pulverized stone for use in lime manufacture. Ballast is a crushed and sized stone used for such purposes as the bedding of railroad ties, etc. Aggregate, also a crushed and sized stone, is used in the same way as sand and gravel for making mortar and concrete. Agricultural limestone is ground very fine and is applied to soils as a liming material. A large tonnage of limestone also is used in the manufacture of Portland cement.

Some idea of the steps and processes involved in the average lime manufacturing plant may be gained by studying Fig. 1 which pictures the various operations in schematic form.

Quarrying. The production of stone for lime manufacture involves several operations. First, the stone must be taken from the underground deposits by the operation known as quarrying. These quarries are either open pits, as shown in Fig. 2, or mines several hundred feet underground. Since the strata of the natural deposits

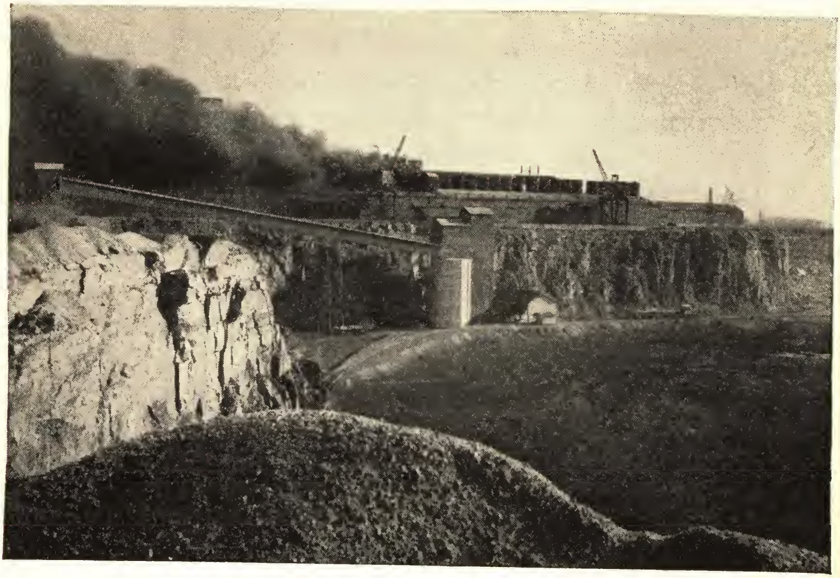

Fig. 2. Open Pit Quarry and Lime Plant
Courtesy of U.S. Gypsum Co., Chicago

usually vary in composition and purity, only that stratum which yields the purest stone of the desired composition is quarried and separated. After drilling and blasting, the larger stones are broken to the desired size and then are carefully selected so that contaminating material may be discarded. This selected stone is conveyed by trucks or cars directly to the kilns, or to the washing and crushing plants if it is to be used for other purposes.

Some manufacturers also wash the stone before it enters the kiln and in some plants the stone is subjected to a rather elaborate beneficiation or refining process in order to bring its composition to a close approximation of 100 per cent purity.

Kiln Burning. Temperatures to 2500° F. drive off the gaseous carbon dioxide, leaving the calcium oxide in the kiln. Kilns are of two general types known as shaft kilns and rotary kilns. Typical rotary kilns are shown in Fig. 3.

SHAFT KILN. In general, a shaft kiln resembles a short, wide stack, circular in cross section, and consists of a casing of steel lined with a material, usually firebrick, which is resistant to high temperatures

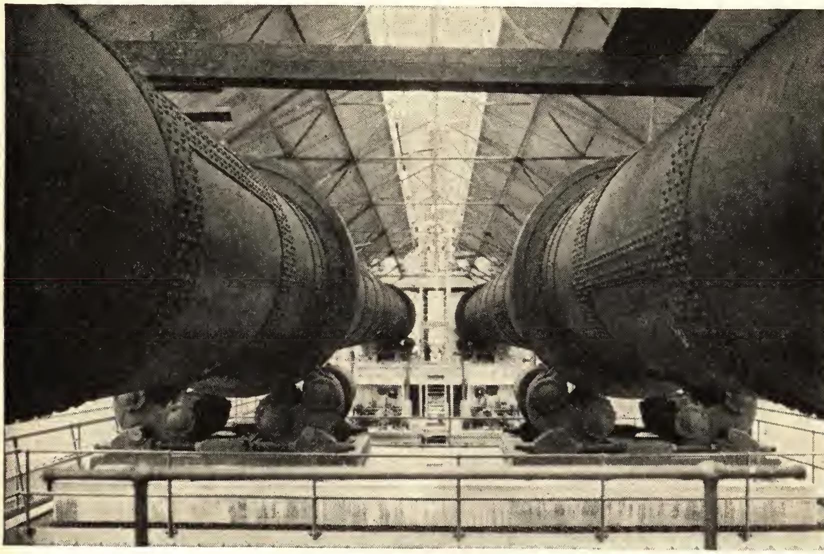

Fig. 3. Rotary Kilns Burning Lime
Kilns are 9 feet in diameter and 175 feet long. Daily capacity is 170 tons of pebble quicklime each, per day.
Courtesy of Marblehead Lime Co., Chicago

and to the chemical action of the lime. From top to bottom the kiln comprises three zones: the top acts as a storage space and serves to preheat the stone; the central serves as the *calcining* zone; and the lower is the cooling zone for the lime which has been calcined. The inside walls slope in such a way that the stone may slide down through the kiln. Fuel for producing the heat which calcines the lime is burned in fireboxes, usually outside the actual shaft and located just below the central or heating zone. Wood, coal, oil, and gas are the fuels used. The natural draft produced by the combustion of the fuel draws the flame and heat up through the shaft into direct contact with the lime and the stone, and the gases pass out through or near the top of the kiln. In some kilns forced draft is used.

The shaft or vertical kiln is fed with lumps of stone varying from 4″ to 12″ in diameter because it is difficult to burn satisfactorily stone of smaller sizes in this type of kiln. Smaller stone is burned in a rotary kiln which is adapted for calcining material usually ranging from ½″ to 1½″ in diameter. The shaft kiln produces lump lime while the product of the rotary kiln is usually referred to as pebble lime.

Fig. 4. Interior of Rotary Kiln
Courtesy of Marblehead Lime Co., Chicago

The smaller the range in stone sizes, the more uniform is the quality of the lime.

Rotary Kiln. The rotary kilns are long, steel cylinders lined with refractory brick (see Fig. 4) and slightly inclined from the horizontal. The length varies, but few kilns are less than 150′ long and their diameter varies between 8 to 10 feet. The kilns are fired by gas, oil, or powdered coal, and the heat is introduced at the discharge end. Owing to the smaller size of the stone, the time required for burning is considerably less than in shaft kilns. The stone passes through the rotary kiln continuously and is completely calcined by the time it reaches the discharge end where it usually enters a continuous rotary cooler.

Inspection. The quicklime from the shaft kiln is inspected carefully and all unburned lime and unburned stone (core) as well as other impurities are removed. The lime from either type of kiln may be marketed in the form in which it is obtained, or it may be crushed and/or pulverized and screened. The degree of crushing and pulverizing is determined by the particular use to which the lime is to be put.

Hydration. Quicklime which is to be used for the manufacture of hydrated lime usually is finely ground and fed to the hydrator. A typical lime hydrator and storage tanks are shown in Fig. 5. Various types of hydrators are in use. If the hydrated lime is to be used in the form of a slurry (milk of lime for use in industrial processes), it is produced by slaking the quicklime with an excess of water. Commercial hydrated lime, however, is a dry powder made by the reaction of the quicklime with the quantity of water required to combine chemically with quicklime to yield a dry product. This process most commonly is continuous, the ground quicklime being mixed with the required amount of water either before or as it enters the hydrating equipment. Many hydrators are equipped with automatic controls which govern the amount of water added so that the emerging product is dry and contains no unhydrated calcium oxide. To complete the hydration of some limes, the hydrator is closed and the reaction takes place at pressures above atmospheric. The increased pressure results when some of the water is vaporized by the heat which is produced by hydration. Other processes attain complete hydration by means of a longer reaction time at or near atmospheric pressure, usually by storage in tanks designed for this purpose as shown in Fig. 5.

Pulverization. After hydration, the lime is ground or pulverized and air separated to remove coarse particles and produce a finely divided material. Pulverizing and air-separating equipment is shown in Fig. 6. For certain uses, the product from the air separators must be so fine that 99.9 per cent will pass a sieve having 160,000 holes per square inch (sieve No. 400).

Packaging, Storage, and Shipping. From the mill or air separator, the lime is conveyed to automatic baggers where exactly 50 pounds is introduced into each bag, the form in which lime is most frequently marketed. Some purchasers who require large quantities obtain the material in bulk cars and remove it by vacuum unloaders or conveyors which carry it to storage bins or to the equipment in which it is to be used. One of the advantages of hydrated lime is that it may be stored in almost any type of equipment as long as it is protected from exposure to water or from excessive exposure to moist air. Quicklime, however, must be thoroughly protected from exposure and therefore is shipped in moisture-resisting bags or drums or in tight

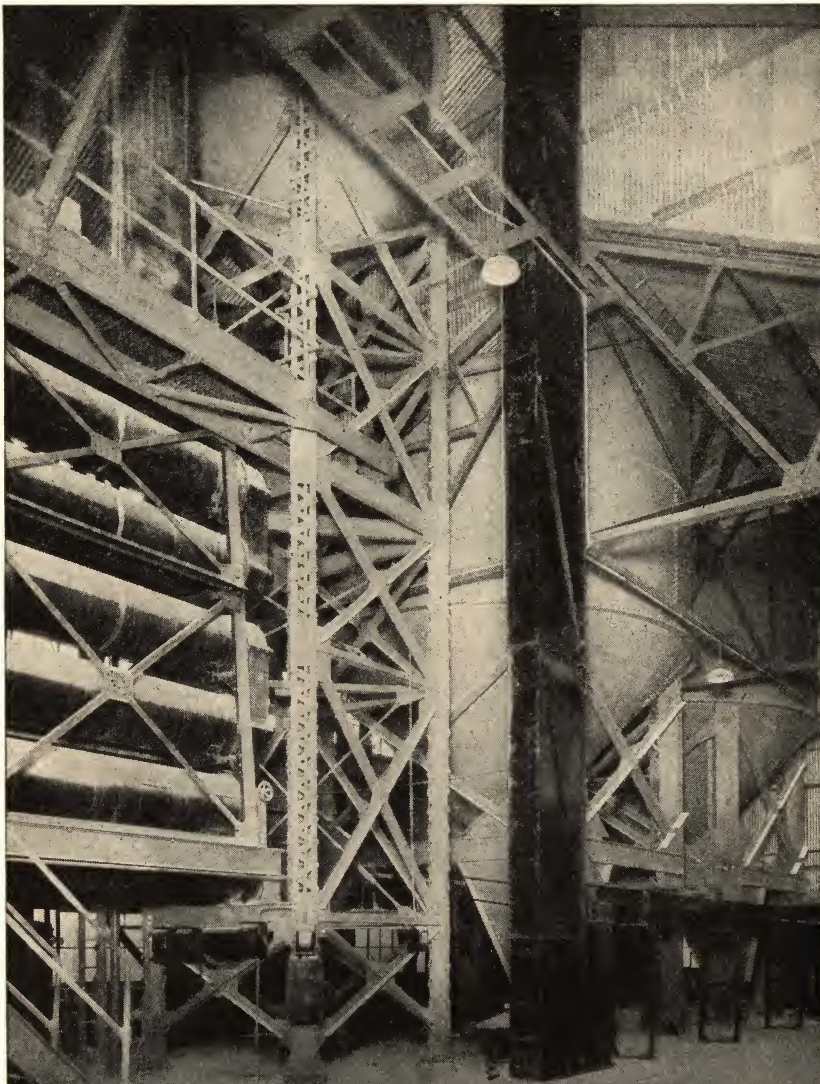

Fig. 5. Lime Hydrator and Storage Tanks for Hydrated Lime
Courtesy of Marblehead Lime Co., Chicago

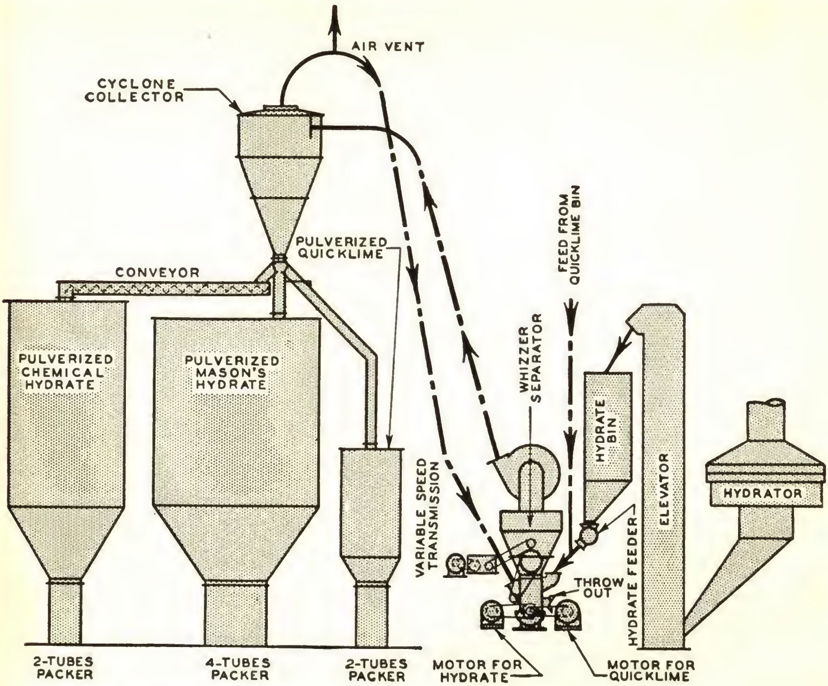

Fig. 6. Flow Sheet Showing Lime Pulverizing and Air-Separating Equipment

barrels. Tight cars are necessary for bulk shipments. Tight metal or concrete bins are usually provided for storage of any large quantity of bulk quicklime; it should not be stored in wooden bins or in containers made of materials which are inflammable or which are not heat resistant. As a result of hydration and carbonation, quicklime becomes air-slaked on long exposure to moist air. This air-slaked lime may or may not be satisfactory for structural uses, depending on the degree of carbonation which has taken place.

PROPERTIES OF LIME

Physical and Chemical Characteristics. The properties and characteristics of lime are best classified under the two general divisions, physical and chemical. The physical properties of a substance are those characteristics of composition which do not change; the chemical properties are those characteristics of composition which do change

to produce one or more entirely new and different substances. These properties of lime are well illustrated by the following examples.

When lump quicklime is crushed and ground to a fine powder it undergoes only a physical change because its form and appearance alone are altered and its composition is not affected. In other words, the pulverized product still is quicklime. On the other hand, quicklime, when added to water, reacts to form a new material which is called slaked or hydrated lime and an appreciable amount of heat is produced during the reaction. The physical and chemical properties of limes are of great importance in connection with its many uses.

Quicklime is marketed in such various physical forms as lump, pebble, granular, and pulverized. These forms may require different methods of handling and use. For example: as a rule, pulverized quicklime will slake more rapidly than the lump quicklime from which it is made; a pebble lime produced in a rotary kiln is somewhat more rapid slaking than the lump lime produced from the same stone in a shaft kiln; most of the calcium quicklimes also slake somewhat more rapidly than the dolomitic quicklimes. It is apparent, then, that different procedures must be used in slaking the various limes.

As previously explained, quicklime reacts chemically with water to produce hydrated lime. Quicklime and hydrated lime, therefore, are two distinct and different chemicals. Quicklime is known chemically as calcium oxide and has the chemical formula CaO which indicates that it is a compound of the metal, calcium (Ca) and the gas, oxygen (O). The chemical reaction involved when lime is produced by calcining limestone is described in the following equation:

$$\underset{\text{Calcium Carbonate}}{CaCO_3} + \underset{\text{Heat}}{\Delta} = \underset{\text{Calcium Oxide}}{CaO} + \underset{\text{Carbon Dioxide}}{CO_2}$$

In other words, limestone is a compound of calcium oxide and carbon dioxide and the heat dissociates the two, driving off the volatile carbon dioxide gas, leaving the solid quicklime. In a similar manner, chemists illustrate the reaction involved in the slaking (hydration) of quicklime by the equation:

$$\underset{\text{Calcium Oxide}}{CaO} + \underset{\text{Water}}{H_2O} = \underset{\text{Calcium Hydroxide}}{Ca(OH)_2} + \underset{\text{Heat}}{\Delta}$$

Hydrated lime thus is a compound of calcium, oxygen, and hydrogen, or of calcium oxide and water ($CaO \cdot H_2O$).

Standard Specifications to Control Variation. Since there are so many possible variations in lime due to the differences in the limestone from which it is derived, as well as varying production procedures, the lime industry, through the efforts and medium of the National Lime Association, has established standard specifications and tests for lime products. Most manufacturers indicate on the lime bags or other containers that the product meets the standard requirements of these specifications. Certain organizations such as the American Society for Testing Materials and various agencies of the Federal Government also have similar specifications for limes which are purchased on contracts. When the lime purchased carries on the containers the statement that the contents meet the requirements of either the National Lime Association or the other standard specifications, the customer or user is assured that the material will give entirely satisfactory results if properly used. Most manufacturers include on the container their recommended method for slaking of quicklime and usually some information as to how it shall be used to secure best results.

Plasticizing Effect of Lime on Mortar. As stated in a succeeding chapter, mortar must be easily and conveniently workable in order that it may be handled and placed with the greatest facility. In addition, it must be of such a nature that a continuous watertight bond is made between the mortar and the masonry units such as brick, tile, concrete block, etc. In order to yield such a mortar, the lime or lime putty must exert a certain minimum plasticizing effect on the mortar. This desired effect is produced as a result of several properties of the lime, including plasticity and water retentivity as perhaps the most important. All manufacturers control the production processes so as to produce lime having plasticities and water retentivities above the minimum figures established in the specifications.

Water Retentivity. The water retentivity of a lime is its ability to hold water so that when the mortar is placed between the masonry units, the suction action of the units will not remove so much water that the mortar becomes stiff and unworkable, making it difficult to bed the units properly and to obtain a satisfactory, well-filled joint. If the water retentivity is too low, the units cannot be bedded properly, the joints may not be filled completely, and there will not be a continuous watertight bond. The result is a leaky job of masonry.

With high water retentivity, a good, watertight job can be produced. Specifications, therefore, always include requirements for water retentivity.

PREPARING LIME FOR USE

Directions for Slaking. Quicklime can never be used as such for structural purposes; first, it must be slaked in water to a putty. Either high-calcium or dolomitic quicklime may be used. The slaking characteristics of the different forms of lime make it necessary to exercise care that the proper slaking procedure is used for that particular lime. If the manufacturer's recommended method for slaking is available, it should be followed. If this is not available, then the first step is to find out by preliminary tests how the lime at hand should be handled. A little extra care during the operation of slaking will amply pay for itself by insuring the production of the greatest quantity of high-grade putty. The following general directions, as given in the lime specifications, should be followed:

Place in a bucket two or three lumps of lime about the size of a fist, or, if using pebble, granular, or pulverized lime, an equivalent amount. Add sufficient water to barely cover the lime and note how long it takes for slaking to begin. *Slaking has begun when pieces split off from the lumps or when the lumps crumble.* Water of the same temperature should be used for test and field practice. As an arbitrary method of classification, it may be said that if slaking begins in less than 5 minutes, the lime is quick slaking; from 5 to 30 minutes, medium slaking; over 30 minutes, slow slaking.

For preparing putty for job use, provide a clean, watertight mortar box. A box of convenient size is 6′ to 8′ long, about 4′ wide, and 12″ deep. In Fig. 7, workmen are shown slaking lime in such a box. The better boxes are made of good 2″ lumber and are lined with sheet iron. Although the lining is not necessary if the box is tight, it is most convenient because of the ease of cleaning and the increased durability of the box. Place 25 gallons of water in the box for each 100 pounds of high-calcium quicklime or 15 gallons for each 100 pounds of dolomitic lime.

Quick-Slaking Lime. For quick-slaking lime, always add the lime to the water, not the water to the lime. Provide sufficient water at first

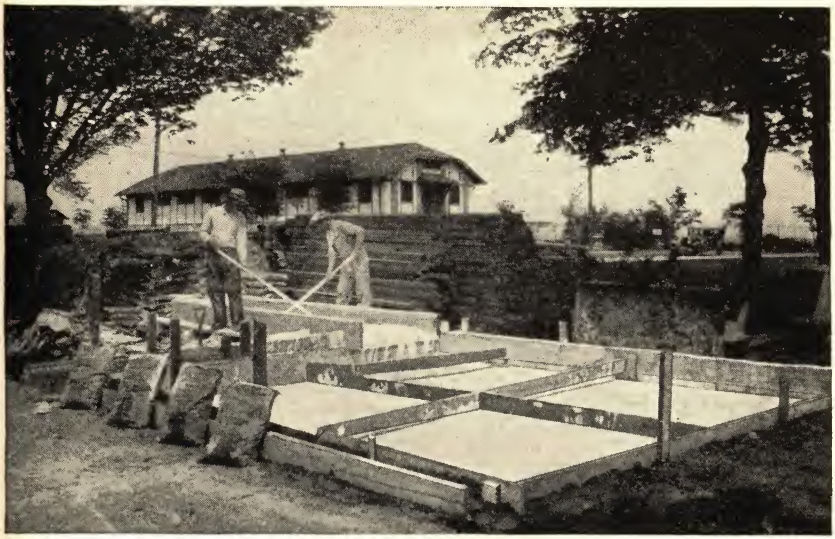

Fig. 7. Slaking Quicklime
After slaking, the putty is run off into cooling boxes shown in foreground.

to cover all the lime completely. Have a plentiful supply of water available for immediate use—a hose throwing a good stream if possible. Watch the lime constantly. At the slightest appearance of escaping steam, hoe thoroughly and quickly and add enough water to reduce violent steaming.

Medium-Slaking Lime. For medium-slaking lime, add the water to the lime—enough so that the lime is about half submerged. Hoe occasionally if steam starts to escape. Add a little water now and then if necessary to prevent the putty from becoming dry and crumbly. Be careful not to add any more water than required, and not too much at a time.

Slow-Slaking Lime. For slow-slaking lime, add enough water to the lime to moisten it thoroughly and let it stand until the reaction has started. Cautiously add more water, a little at a time, taking care that the mass is not cooled by the fresh water. Do not hoe until the slaking is practically complete. If the weather is very cold, it is preferable to use hot water but if this is not available, the mortar box may be covered in some way to retain the heat.

Best results are obtained with any lime when the slaking mass is

allowed to reach the boiling point and in fact actually boils during the process. This is necessary for thorough hydration and to develop the full plasticity and strength of the lime.

After the action has ceased, run off all the putty, except that from pulverized quicklime, through a 20-mesh screen into clean mortar boxes such as those shown in Fig. 7, and allow it to cool until it has reached a temperature of 80° F. or below. This cooling time will vary depending on the volume of putty and the atmospheric conditions. The lime industry specification emphasizes the requirement that the finished putty shall weigh at least 80 pounds per cubic foot and only sufficient water to yield a putty of this minimum weight should be used in the slaking.

Commercial Hydrated Lime. Commercial hydrated lime is a white powder composed of extremely fine particles. It is only slightly soluble in water. For structural uses, this product has the advantage over quicklime in that it does not require slaking and can be added dry to the mortar without previous soaking. Time and labor are thus saved, so, although the material costs more per ton than quicklime, the over-all cost of mortar made from it may be less except for the larger jobs or on smaller jobs where slaking equipment is available.

USES AND FUNCTIONS OF LIME IN CONSTRUCTION

Lime is used in practically all masonry mortars and grouts. Such uses are described in succeeding chapters. It is also used in plaster base coats, except where building codes specify cement plaster, and in all plaster finish coats. Fig. 8 shows workmen preparing lime putty for a plaster finish coat. It is used in much of the cement and asphaltic concretes in buildings and for highways. In cement concrete, lime functions as a plasticizer, making the concrete easier to place, reduces honeycombing, and improves the watertightness and appearance of the finished concrete. In asphaltic concrete, it serves to condition the material properly and acts as a filler. Lime is also frequently applied as a coating on metal reinforcement for concrete and masonry to improve its resistance to corrosion.

Soils of certain types which serve as the foundations for heavy structures frequently are treated with lime to stabilize them against excessive volume changes resulting from changes in moisture content.

Fig. 8. Preparing Lime Putty for Plaster Finish Coat
Courtesy of Carl Brieck, Contractor, Chicago

It is good practice to lime heavy clay soils which are used as backfills against foundations and retaining walls for the purpose of improving the drainage and thus increasing the life of the wall. Soils for building dirt roads in some sections of the country are treated with lime. In many instances, the soil subgrades under concrete and other hard-surfaced highways, airport runways, etc., are limed to reduce volume changes which would otherwise greatly reduce the life of the roadway.

In stucco for both interior and exterior applications, lime increases workability, improves appearance, and makes the stucco more durable. The cement-lime stuccos are easily worked and are practically permanent when properly applied on acceptable backings.

Another construction use of lime is in the manufacture of sand-lime brick. In this process, the lime reacts with a small portion of the sand to produce a cementing material which binds together the sand

particles producing a strong structural unit similar to clay brick. Lime is also used as a whitewash and in the manufacture of certain cold-water paints.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. What the term calcining means?

Answer. Calcining is a name given to the process in which limestone is heated to a high temperature or burned.

2. What happens when quicklime comes in contact with water?

Answer. There is a chemical reaction which produces a large amount of heat. Sometimes this reaction is almost explosive in nature.

3. How the two general types of quicklimes can be distinguished?

Answer. By the rate at which they react with water or in other words, by the activity of the slaking and by the temperature produced during slaking.

4. How gaseous carbon dioxide is separated or driven out of limestone?

Answer. By heating the stone to 2500° F. in kilns.

5. What type of kiln is used to burn stone in sizes of 4″ to 12″ lumps?

Answer. The shaft or vertical kiln.

6. What type of kiln probably produces the most uniform quality of lime?

Answer. The rotary type because the size of the stones fed into it range no larger than 1½″ in diameter.

7. One advantage of hydrated lime?

Answer. It may be stored safely in almost any type of equipment as long as it is protected from exposure to water or to excessively moist air.

8. Whether lump quicklime slakes more rapidly than pulverized quicklime?

Answer. Pulverized quicklime slakes more rapidly than lump quicklime.

9. What must be done to quicklime before it can be used for structural purposes?

Answer. It must be slaked in water to a putty.

10. How much water should be used to slake 100 pounds of high-calcium quicklime?

Answer. Use approximately 25 gallons of water.

11. How to combine the water with quick-slaking lime.

Answer. For quick-slaking lime, always add the lime to the water, not the water to the lime.

12. How best results are obtained when slaking any lime?

Answer. The best results are obtained by allowing the slaking mass to boil a while.

13. What is meant by the water retentivity of a lime?

Answer. The water retentivity of a lime is its ability to hold water so that, when the mortar is placed between masonry units, the suction action of the units will not remove so much water that the mortar becomes too stiff.

14. What function lime performs in cement concrete?

Answer. It functions as a plasticizer and makes the concrete easier to handle or place, reduces honeycombing, and improves the watertightness and appearance of the finished concrete.

15. Why soils which serve as foundations for heavy structures are sometimes treated with lime?

Answer. To stabilize them against excessive volume changes resulting from changes in moisture content.

16. When hoeing should be done when slaking slow-slaking lime?

Answer. Not until the slaking is practically complete.

17. When hoeing should be done for quick-slaking lime?

Answer. Start hoeing when the first and slightest appearance of escaping steam can be noticed.

REVIEW QUESTIONS

1. What is the solid product called which remains after limestone has been heated to a high temperature?
2. How might the calcining process have been discovered originally?
3. What is slaked or hydrated lime?
4. What two general types of limestones are generally used for making lime?
5. Name the two general types of quicklimes and explain why they are different in character.
6. What type of lime slakes the most rapidly? Why?
7. When gaseous carbon dioxide is separated from limestone by heat, what type of oxide remains?
8. What happens to quicklime after long exposure to moist air?
9. Will calcium quicklimes slake more rapidly than the dolomitic quicklimes?
10. Why must care be exercised that the proper slaking procedure is used for each type of lime?
11. Explain the procedure by which the slow or rapid slaking qualities of a lime can be determined.
12. Explain the procedure of combining the water with medium-slaking lime.
13. How can thorough hydration be assured when slaking lime?
14. How much should finished putty weigh per cubic foot?
15. Explain how to prepare putty for job use.
16. What types of quicklime can be used for structural purposes?
17. How is milk of lime produced?

CHAPTER II

Mortar Types, Properties, and Uses*

QUESTIONS CHAPTER II WILL ANSWER FOR YOU

1. *What are the most commonly used cementitious materials?*
2. *In coloring mortar, why should only the minimum quantity of pigment required to produce the desired color be used?*
3. *How does the Masonry Code of the American Standards Association help solve the problem of selecting a particular mortar to meet specific use requirements?*
4. *What are the contributions of mortar to the characteristics of finished masonry?*
5. *What are some of the more important and useful bulletins relative to mortar and its uses?*

INTRODUCTION TO CHAPTER II

Undoubtedly you have heard the old saying, "A chain is only as strong as its weakest link." A parallel to this bit of wisdom can be found in unit masonry, for any structure is only as good as the mortar which binds the units together. A wall made of the costliest, most durable clay tile, brick, or concrete blocks and laid by the most skillful and competent masons is worthless if the mortar in the joints is inferior. That the Romans and other noteworthy builders of antiquity recognized this is evidenced in the structures uncovered by archaeologists in recent years. Examples of walls, foundations, piers, aqueducts, bridges (some of which are still in use in Europe), etc., have been found with the mortar intact and just as strong and serviceable as when it was first incorporated in the structure.

A comprehensive study of these early examples of masonry construction was compiled by two representatives of the Building Research Organization of the British Government and portions of it apropos to the study of mortar have been used as an introduction to this chapter. This short history of mortar provides interesting reading but at the same time it serves as the groundwork for the important information that follows.

You will learn first, of the various mortar types and the materials comprising these mortars. You will be told how to proportion and mix mortar. Its many properties will be described for you. You will learn the selection and application of mortar on the basis of its intended use. Eventually you will wish to refer to the useful tables and bibliography at the end of the

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*This chapter was developed through the co-operation of Dr. G. J. Fink, Executive Secretary of the Oxychloride Cement Association, Washington, D.C.

chapter. These will be of tremendous value later in planning and building masonry structures.

When you have thoroughly acquainted yourself with the mass of important information contained in this chapter, you will be adequately prepared to undertake the study of the problems involved in unit masonry construction.

DEFINITION, FUNCTIONS, REQUIREMENTS

Mortar for unit masonry may be defined as a compound of cementitious materials and sand with sufficient water to reduce the mixture to a workable consistency. A mortar is termed grout when enough water has been added to yield an easily flowing mixture.

The functions and requirements of a mortar in masonry construction of any type, including brick, stone, hollow tile, and concrete or cinder block, are: it must possess sufficient plasticity and workability to allow it to be handled and placed with ease; it must provide a uniform bearing or bedding for the units; it must bind the units together; it must fill completely all joints and produce a continuous contact with the units to prevent penetration of water into the wall through the joints; and it must contribute sufficient strength and durability so that the finished masonry will withstand the vertical and lateral stresses and the exposures to which it is subjected under the specific conditions of use.

HISTORY

No records are available indicating the use of mortar for building purposes before the development of civilization to a relatively advanced stage. Two general types of construction are found among the earlier structures. In one of these the walls were built by ramming together successive layers of earth to obtain a relatively strong, compact mass, while in the other type, heavy blocks of stone were set one above the other in regular form without the use of any binding material, stability depending on the great weight of the stones and the care with which they were bedded against each other.

The early history of the development of masonry practices is well described by the British scientists, F. M. Lea and C. H. Desch, of the Building Research Organization of the British Government, from whose book[1]* the following passage is quoted.

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* Numerals refer to literature listed at the end of this chapter.

Although remarkable works have been accomplished by such methods of construction (i.e., heavy stones placed without mortar), notably in the domed chambers of Mycenae, where small stone wedges were driven between the large blocks in order to tighten the joints, yet Cyclopean work has always given place in later times to masonry or brickwork, erected with the aid of some plastic material.

The simplest plan is that found in the brick walls of ancient Egyptian buildings. The bricks were dried in the sun without baking and each course was covered with a moist layer of the loam (Nile mud) used for making the bricks, with or without the addition of chopped straw. The drying of this layer made the wall a solid mass of dry clay. Such a mode of construction is only possible in a rainless climate as the unburnt material possesses little power of resistance to water. Burnt bricks and alabaster slabs were employed by the Babylonians and Assyrians and were cemented together with bitumen. This method was very efficacious but, being necessarily confined to those regions in which natural deposits of the material occur, it was not copied elsewhere.

In the massive masonry constructions of the Egyptians, the present-day system of uniting blocks and slabs of stone with a mortar, consisting of a mixture of sand with a cementitious material, originated. While the typical Egyptian mortar has been generally described by writers on Egypt as burnt lime, even where found in buildings as old as the Great Pyramid, chemical examination shows that the Egyptians never used lime until the Roman period and that the cementing material was always obtained by burning gypsum. . . .

According to the valuable work of A. Lucas, the reason for using gypsum instead of lime, although limestone was more abundant and more accessible than gypsum, was the scarcity of fuel, lime requiring a much higher temperature, and consequently more fuel for its calcination.

The Greeks must have adopted lime at an early period, possibly from Persia, and the Romans must have borrowed it from them. The mortar was prepared in the modern fashion, by slaking the lime and mixing with sand, and the examples of Roman brickwork which still exist are sufficient evidence of the perfection which the art attained in ancient times. The remarkable hardness of the mortar in walls of Roman workmanship puzzled many engineers and has sometimes led to the assumption that some secret was possessed by the workmen which is now lost, but a comparison of the analyses of the mortar with the descriptions of the method by ancient authors gives no ground for such a supposition.

. . . Rondelet, after a careful examination of Roman buildings and after making many experiments with the methods proposed by Loriot and others, came to the conclusion that the excellence of Roman mortars depended, not on any secret in the slaking or composition of the lime, but on the thoroughness of mixing and ramming.

Rondelet's explanation is without doubt correct. Analyses show nothing abnormal in Roman mortars but the texture is very close and the interior is often found to contain lime which has not become carbonated, showing the impermeability of the mortar to gases. The practice of long-continued ramming is confirmed by Indian experience. In Bengal, where finely ground brick

replaces the whole or part of the sand, lime and ground brick (surki) are mixed wet until a sticky mass is formed and this is then added to the aggregate, the whole being mixed thoroughly and rammed into place. After this, tamping is kept up for several hours until, on scooping a hole and filling it with water, this is not absorbed.

Both the Greeks and the Romans were aware that certain volcanic deposits, if finely ground and mixed with lime and sand, yielded a mortar which not only possessed superior strength but was also capable of resisting the action of water, whether fresh or salt. The Greeks employed for this purpose the volcanic tuff from the island of Thera (now called Santorin), and this material, known as Santorin earth, still enjoys a high reputation in the Mediterranean area. The mortar used at the present day by peasants of Santorin—an island destitute of wood for building—is identical in its composition and preparation with that of ancient times.

The corresponding material of the Roman builders was the red or purple volcanic tuff found at different points on and near the Bay of Naples. As the best variety of this earth was obtained from the neighborhood of Pozzoli or Pozzuoli (in Latin Puteoli), the material acquired the name of Pozzolana and this designation has been extended to the whole class of mineral matters of which it is a type. . . .

The Romans carried their knowledge of the preparation of mortar with them to more remote parts of their Empire and the Roman brickwork found in England, for example, is equal to the best of that in Italy. The use of Rhenish volcanic tuffs known as Trass was probably introduced at this time, and this material, like pozzolana, is still very largely employed at the present day.

These authors then describe the deterioration in the quality of mortars which began after the decline of the Roman Empire and continued through the Middle Ages. This most probably was brought about by the improper use of good mortar materials or the use of poor quality cementitious materials and aggregates. There followed, in more recent times, the discovery and development of hydraulic limes (about 1750–1760), improvements in the lime-pozzolana mixes, the use of natural cements, and finally, the invention and use of Portland cement. With improvements in the manufacture and quality of Portland cement and lime during the last two decades, the use of cement-lime mortars has become quite general. The development of the so-called "patent cements" or masonry cements is relatively recent.

This chapter describes in general terms and with a minimum of technical detail, the methods of preparation of the various types of mortar, their specific characteristics, and the generally accepted practices in their use, the purpose being to provide a body of usable

information for those interested in the problem of good masonry. References are given to various publications which will serve as sources of information for those who desire further technical details and data.

MORTAR TYPES AND MATERIALS

For the purpose of discussion mortars may be classified into five general types on the basis of the composition of the cementitious material. These are: straight lime mortars, straight cement mortars, cement-lime mortars, masonry cement mortars, and lime-pozzolana mortars. On the basis of proportions, cement-lime mortars usually are classified in accordance with the ratios of cement to lime, the more commonly used compositions being 1:¼:3, 1:1:6, 1:2:9, and 1:4:15, or types A, B, C, and D, respectively. The figures represent the relative proportions by volume of cement to lime to sand.

As indicated by the definition, the primary components of a mortar are the cementitious material, the aggregate, and water. Each of these serves its particular and essential function and each should be of the best quality available in the locality but within the prescribed cost limits of the job. Masonry should be built for permanence and from this point of view the cost consideration should not be so important that the ultimate goal of a durable structure of pleasing appearance cannot be attained. Fortunately, the great majority of the cements and limes available are as good as can be produced economically with our present scientific and technical knowledge of raw materials.

Through the co-operation of manufacturers' representatives, scientific bodies, the Federal Government, and the consuming public, specifications for each of the various components of mortars have been developed. (See literature at end of chapter indicated by numbers 2, 3, 5, 6, 7, 8.) The specifications for every job should demand that all materials furnished meet all the requirements established by these specifications. All reputable manufacturers will gladly certify that their products conform to the standard specification requirements and most of them are members of responsible trade associations which are in a position to supply literature describing how the material should be used to obtain the best results. These organizations maintain extensive research laboratories and technical staffs. They co-operate with various scientific bodies; with federal departments such as the

National Bureau of Standards, the Federal Public Housing Authority, and the Federal Specifications Executive Committee; with the corresponding industry organizations representing the manufacturers of all other building materials; as well as with architects and contractors. The literature supplied by these trade associations is authoritative and incorporates all of the required information which is currently available. Additional publications and copies of published articles giving the more scientific and technical information also are usually available. Any such literature not available through dealers in building materials can be obtained from the individual manufacturers or from the particular associations. A list of the more important publications giving general information is included at the end of this chapter.

Cementitious Materials. Cementitious materials, as the name indicates, are used to bind together the particles of aggregate (sand) and, in turn, to bind the brick, stone, or other units into a continuous unit structure. The most commonly used cementitious materials are lime, Portland cement, and masonry cement. Natural cement and lime-pozzolana mixtures are used occasionally, either singly or in various combinations.

LIME. In addition to its action as a cementitious material, lime contributes many other properties to a mortar. It imparts plasticity, workability, and water-holding capacity (water retentivity) to the mortar. Its presence decreases the tendency of the mortar to lose water, which is known as bleeding, and reduces separation or segregation of the sand. Consequently its use makes the job of filling the joints easier and more likely to be accomplished. Harsh mortars are difficult to work and are likely to result in unsatisfactory masonry.

Either hydrated lime or quicklime putty is used in making mortar. Any brand of either which conforms to the minimum standard specification requirements will prove satisfactory, but in general, with a given cement and sand, the workability and water retentivity of cement-lime mortars increase as the water retentivity of the lime increases. Quicklime cannot be used as such and is always employed as a putty made by slaking the quicklime. Most hydrated limes may be added to the mortar box without preliminary soaking but some manufacturers recommend that their product be soaked overnight (at least for 12 hours) to enhance the plasticizing effect.

Cements. When cement is mixed with water, it is plastic for a short time, then sets in air or water and develops a considerable portion of its ultimate strength in a few days. It then possesses qualities of permanency to the extent that no material change in shape or volume will take place because of its inherent qualities or as a result of exterior agencies. There is more or less shrinkage in a volume of cement during the process of setting or hardening, and like many other building materials, there is a change in volume caused by change in temperature. Cement mixed with sand and water is called cement mortar. When stone and gravel or some other inert material is added to the cement, water, and sand, the resulting mixture is concrete.

The cements most commonly used are as follow:

Portland Cements. Portland cements[9] are quite uniform commercial products and when the term cement is used without qualification, Portland is usually the type to which reference is made. To avoid misunderstandings, it should always be called Portland cement.

The specifications of the American Society for Testing Materials[13] (A.S.T.M. C150-44) cover five types of Portland cement and establish requirements relative to the physical properties and chemical composition for each type. Cement of any one of these types is satisfactory for use in mortars, but types I and III are those generally used. The other three are more or less special and may be required for specific conditions of use, usually in concrete, where the first two types mentioned would not give the best result. Unless high early strength is required, type I is generally specified for unit masonry construction. The common Portland cement is gray in color, but white Portlands are available also when a white mortar is required.

Air-Entraining Cement. There has been developed recently an air-entraining cement. This product contains small quantities of a chemical which increases the amount of air held by the mortar or concrete made from the cement. The additional air usually improves the workability of the mortar and concrete and increases the resistance to freezing and thawing. The strength, however, is usually less than that obtained with the average untreated cement. Such cements are not required for average construction but may be specified for special jobs where the specific use requirements would best be met by a material of these characteristics.

Portland-Pozzolana Cements. The Portland-pozzolana cements are produced by grinding together Portland cement clinkers and a pozzolanic material. They are coming into use for making concrete because, as reported by a committee of the American Concrete Institute,[4] the "substitution of pozzolanic material for part of the cement generally improves workability, reduces bleeding and segregation, reduces heat of hydration, though not in proportion to the amount substituted, improves impermeability to water and increases resistance to aggressive attack of sea water. . . ." Fly ash, volcanic ash, heat-treated diatomaceous earth, and heat-treated or raw shales or clays are among the pozzolanic materials used in amounts ranging from 10 to 30 per cent of the weight of the Portland cement. The requirements for these cements are covered by the Federal Specification SS-C-208a, entitled, "Cement; Portland, Pozzolana."[5] Such cements are used in masonry mortars for special use requirements as, for example, when the masonry is to be in constant or intermittent contact with salt water or high-sulfate soils. They may in all cases be used in place of Portland cement, if desired.

Masonry Cements. Masonry cements are mixtures prepared by the manufacturers and their composition is rarely disclosed. Tests made by the National Bureau of Standards in 1934 on forty-one commercial masonry cements in use at that time showed[8] "that the cements could be classified as hydraulic lime, hydrated lime, natural cements, blast-furnace-slag cements containing various additions, several cements whose composition could not be positively determined, or Portland cements with and without admixtures, the proportions of which varied from small amounts to amounts larger than the quantity of Portland cement. About half of those studied contained water-repellent additions." The results of these tests indicated a wide range in the properties of the various products. Since that time, a few commercial masonry cements have been improved with respect to some of their properties. Since many of the manufacturers do not disclose the composition of their products, these cements can be judged only on the basis of the properties of the mortar produced.[11] In the absence of tests of the mortars and without reliable performance records of the particular products, the purchaser must rely upon standard specifications of either the A.S.T.M.[3] or on the Federal Government.[5]

Natural cements and slag cements may be classified as masonry cements for the purpose of this discussion. Natural cements are produced by calcining limestones which contain appreciable amounts of clay. The calcined product is finely ground and may be mixed with a minimum of 5 per cent of nondeleterious materials subsequent to calcination. Owing to the usual variations in the composition of the original stone from which natural cements are made, the products are rarely uniform and their use alone as a cementitious material is limited to a few localities. They are a constituent of some of the masonry cements.

Slag Cements. Slag cements are a particular type of lime-pozzolana or masonry cement and are made by grinding together lime and blast-furnace slag to produce an intimate mixture. The slag functions as the pozzolanic material. As a rule they are not used alone but are mixed with further quantities of lime at the time of use.

Lime-Pozzolana Cements. This type of cement is made by grinding together hydrated lime and some pozzolanic material such as volcanic ash, heat-treated clay, blast-furnace slag, ground clay brick or tile, etc. Although used quite extensively in continental Europe and Asia where volcanic ash of suitable properties is widely available, it is rarely utilized on our continent where Portland cement can be obtained readily in almost every locality. The lime-pozzolana mixtures, when combined with sound aggregates, yield mortars or concretes which will set while in contact with water and which are more resistant to the action of sea water than those made from Portland cement. In this respect they are similar to the Portland-pozzolana type, although as a rule, they set more slowly and attain their maximum strengths only after an appreciably longer period.

Aggregates. Practically all cementitious materials, if used alone as a mortar, would shrink to such an extent that cracks would develop in the joints between the masonry units the mortar was supposed to bind together. To avoid this and also to make the mortar more economical in cost, some inert material such as sand is always mixed with the cementitious material in the proper proportions to overcome most of the potential shrinkage. These inert materials are termed aggregates.

The specifications for aggregates for masonry mortar[3] of the Amer-

ican Society for Testing Materials require that the aggregate "shall consist of fine granular material composed of hard, strong, durable mineral particles which are free of injurious amounts of saline, alkaline, organic, or other deleterious substances." According to this definition, many minerals could qualify for use as aggregate but ordinary sand is the material most commonly used. It is easily available in almost every locality and is relatively cheap.

Sand must be clean and well graded as to particle size if a satisfactory mortar is to be obtained. Owing to the great differences in the sands of various localities, the standard specifications permit a rather wide range in sizes but a better graded sand, if available, will yield a more workable and better mortar in almost every respect.

The A.S.T.M. requirements for grading represent the extreme limits and it is specified that "the gradation of the material from any one source shall be reasonably uniform and shall not be permitted to vary over the extreme range" and that it "shall be so graded that neither the proportion finer than a No. 16 sieve and coarser than a No. 30 sieve nor the proportion finer than a No. 30 sieve and coarser than a No. 50 sieve exceeds 50 per cent." For purposes of comparison, the following tabulation gives the A.S.T.M. specification ranges of sieve analyses together with the analysis of an average commercial sand and that of one of more nearly ideal grading.

TABLE I. SIEVE ANALYSES FOR MORTAR SAND

Sieve Number	Percentages Passing Each Sieve		
	A.S.T.M. Specifications	Commercial	More Nearly Ideal
4	100	100	100
8	95–100	98	97
16	60–100	88	84
30	35–70	64	50
50	15–35	26	27
100	0–15	5	6

In a good mortar, all the sand particles are completely coated with cementitious material (paste) and hence a sand containing a high proportion of fine particles may require much more paste than either a properly graded material or one made up chiefly of larger particles. However, sufficient fine material should be present to separate

the larger particles and to fill the spaces (voids) between them, thus yielding an easily workable mortar. When all the sand particles are coated and lubricated with the paste of cementitious material, the smaller particles act more or less as ball bearings, thus permitting the particles of aggregates to roll over each other and producing a plastic workable mortar which will serve as a continuous uniform bedding for the brick or other structural units.

Sand from deposits containing clay lumps or organic material should be washed to remove these substances which would adversely affect the mortar strength and durability. Mica, coal, lignite, and other such materials in any appreciable quantity are also classed as undesirable components of sand. Specifications usually require that a sand shall yield a mortar of a certain minimum strength as compared with a mortar made from a standard sand and the same prescribed cementitious material.

Water. The water used in mortar should be clean and practically free from acids, alkalies, salts, and organic substances. Excessive quantities of any of these materials may adversely affect the time and rate of set of the mortar and may be a source of efflorescences and scum on the finished masonry, particularly if it is to be exposed to a damp environment.

Clays. In some sections of the country, finely ground clay has been used during recent years as a plasticizer for mortars. In the absence of definite knowledge and experience as to the permanence of such mortars and because there are as yet no nationally accepted specifications for clay for this use, the purchaser should investigate the records of past performance of the particular clays being proposed and accept only those from which satisfactory evidence can be obtained as to their effects on the properties of the resulting masonry. The same specification requirements as those accepted for other mortars should be met by those including clay.

Admixtures. The question of the desirability of the use of admixtures is more or less controversial. Since suitable mortars can be obtained through the use of the ordinary and readily available materials in most localities without resorting to admixtures, it would appear that the best practice would be to use admixtures only where certain special properties are required in the mortar. The Structural

Clay Products Institute, in its booklet on mortar,[6] states that "Waterproofing and water-repellent admixtures and grinding aids, such as Vinsol Resin, frequently increase the workability of mortar and there are some data to indicate that they also add to the resistance of mortar to freezing and thawing in the presence of moisture." In regard to integral waterproofing materials, this same publication states that "Too much confidence, however, should not be placed in the effect of such additions in preventing moisture penetration of masonry or in reducing shrinkage of the mortar either before or after hardening." Most admixtures tend to reduce the strength of mortar and their presence in any great amount would probably impair its durability. The generally accepted specifications for mortar for reinforced brick masonry do not recognize admixtures.

Mortar Colors. When it is desired to obtain a colored mortar, the use of colored aggregates such as marble, granite, or other similar stone is generally preferred to the use of color pigments. Color obtained with an aggregate is likely to be more permanent and the strength and durability of the mortar is not adversely affected. White cement and lime, with white sand, white limestone, or marble aggregates may be used to obtain white mortar joints.

Strict care must be exercised in the selection of color pigments. In the first place, the pigment must be resistant to the chemical action of the cement and lime. For this reason the so-called earth pigments such as the red, black, yellow and brown iron oxides; manganese black; chromium oxide green; ultramarine blue; and carbon black are the pigments most commonly used. By proper combination of these materials, the desired shades and color effects are usually obtainable. The organic colors and dyes in general do not yield permanent colors in mortars. Best results are usually obtained when white cement, white lime, and white sand are used. Thus purer colors are had, unmodified by any color in the cementitious materials of the mortar. In working the mortar and in tooling the joints care must be exercised not to float the coloring material to the surface. An excellent discussion of the use of color pigments will be found in the report of the American Concrete Institute in their *Journal,* Volume I, No. 6, April, 1930, entitled "The Coloration of Concrete."

Best results are obtained by thoroughly mixing the color with the

dry cementitious material before it is added to the mortar box. The final color of the mortar should be such as to harmonize properly with the color of the brick or other structural units in order to obtain the most pleasing over-all effects. In other words, artistic skill must be exercised in the selection of both brick and mortar colors. Owing to the fact that the majority of pigments simply replace the cementitious material and hence reduce the strength and may possibly adversely affect some of the other properties of the mortar, only the minimum quantity of pigments required to produce the desired effect should be used.

MORTAR PROPORTIONS

Proportion of Cementitious Material to Aggregate. The commonly used proportion of cementitious material to sand in average mortars is 1 part of cementitious material to 3 parts of sand by volume. These proportions may be varied within certain limits, most specifications requiring that the proportion of sand shall not be less than 2 times nor more than 3 times the volume of cementitious material. The selection of the proportion for the particular job must be governed by the properties of the cementitious material and aggregate and by consideration of the use requirements of the mortar. As indicated above, the better graded sands may produce a satisfactory, workable mortar with smaller proportions of cementitious material, whereas the poorly graded sands may require larger proportions of the cementitious material. The higher proportions of sand may be used with the highly plastic cementitious material. In general, the amount of sand used should be near the maximum which will yield a plastic and readily workable mortar. Except in special cases, the sand should not exceed three times the volume of cementitious material. Undersanding a mortar may result in shrinkage cracks and oversanding produces a harsh mortar in which it is difficult, if not impossible, to bed the bricks properly and leaky masonry is likely to be the result.

Proportions of Components of the Cementitious Material. Since the plasticity, strength, and water retentivity qualities of mortar are dependent upon the proportions of cement and lime going into the cementitious material, the specifications for cement-lime mortars are most important.

Portland Cement-Lime Mortars. Straight Portland cement mortars, that is, without lime, and straight lime mortars, that is, without cement, have been used infrequently in recent years. The average Portland cement, when used without lime or some plasticizing agent, yields mortars which are not easily workable. On the other hand, straight lime mortars are quite plastic and workable and have high water retentivity but they stiffen and set too slowly for modern high speed construction. In addition their strengths are relatively low. Mixtures of cement and lime, therefore, are the most generally used cementitious material.

Most existing specifications for cement-lime mortars recognize four different mortar types based on the ratio of the quantities of cement and lime. For example, the "American Standard Building Code Requirements for Masonry,"* which was developed by the American Standards Association[7] and which is sponsored by the National Bureau of Standards, classifies mortar either on the basis of its properties or its composition in terms of proportions by volume, as types A, B, C, and D. The following quotation from their American Standard, A41.1-1944 gives this classification and the code requirements for the particular mortar types.

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* Published under this title by the American Standards Association and designated as their American Standard A41.1-1944. Copies may be had for 50 cents, on request directed to the American Standards Association, 29 West 39th Street, New York 18, New York, or to the National Lime Association, 927 Fifteenth Street, N.W., Washington 5, D.C., the Portland Cement Association, 33 West Grand Avenue, Chicago, Illinois, or the Structural Clay Products Institute, 1756 K Street, N.W., Washington, D.C. All of these three trade associations have approved this Code.

This same standard code is also published by the National Bureau of Standards, Washington 25, D.C., as Miscellaneous Publication M 174 (March 15, 1944). Copies of this publication may be obtained for 10 cents from the Superintendent of Documents, Government Printing Office, Washington 25, D.C.

(c) Mortar of materials conforming to the requirements of Section 2-13, and of any proportions conforming to Section 2–14(b) may qualify as mortar of any one of the four types, provided it conforms to the physical requirements of Section 2-14 (a) and 2-15 (a).

When it is desired to establish the strength classification of a given mortar by test, the strength shall be determined with mortar prepared in a testing laboratory, of representative materials, and in the proportions proposed for use. The test cubes shall be molded, cured and tested for compressive strength as described in the Federal Specification for Masonry Cement, SS-C181b except that for type D mortar the entire curing shall be in laboratory air at 70°F±5°.

2-15. Classification of Mortar. (a) Mortar used in masonry construction shall be classified as follows:

TABLE II. STRENGTH REQUIREMENTS

Type	Minimum Compressive Strength of 2" Cubes at 28 Days
A	2,500 lb. per sq. inch
B	600 lb. per sq. inch
C	200 lb. per sq. inch
D	75 lb. per sq. inch

(b) Unless the strength classification of the mortar has been otherwise established by test as prescribed in section 2-15 (c), mortars of the following proportions, with the aggregates measured in a damp and loose condition, may be assumed to meet the strength classification given in section 2-15 (a).

The same proportions and approximately the same property requirements for mortar types A, B, and C are also recommended by the Structural Clay Products Institute.[6] Mortars of types B, C, and D are covered in National Lime Association specifications[2] NO 1-45 and MS 3-45.

TABLE III. PROPORTIONS BY VOLUME

Mortar Type	Cement	Hydrated Lime or Lime Putty Allowable Range	Aggregate Measured in a Damp and Loose Condition
A	1 (Portland)	0-¼	Not more than 3
B	1 (Portland)	1-1¼	Not more than 6
B	1 (Masonry FS* Type II)		Not more than 3
C	1 (Portland)	2-2¼	Not more than 9
C	1 (Masonry FS Type I)		Not more than 3
D	0-½ (Portland)	1-1¼	Not more than 3 parts for each part of cementitious material

NOTE.—The weights per cubic foot of the materials in mortar are considered to be as follows:
Portland cement: 94 lb.
Masonry cement: weight printed on bag.
Hydrated lime: 40 lb.
Dry sand: 80 lb.

*FS refers to Federal Specifications SS-C-18 lb.

It is generally believed by structural engineers that mortars should be classified and specified on the basis of properties but the code requirements quoted above include also the volume proportion classification because of the fact that some purchasers are not in a position to have tests made on the mortars and mortar materials which are specified for their jobs.

For the purpose of measurement of the required volumes of the cementitious materials and sand, the various specifications in the past have designated the volumes of materials in terms of cubic feet. For this purpose it is assumed that the standard bag of Portland cement contains one cubic foot and that one cubic foot weighs 94 pounds. This assumption is fairly accurate as an average but, owing to the fact that the densities of the various Portland cements differ slightly, some brands weigh a little more and some a little less than 94 pounds per cubic foot. The standard bag of hydrated lime contains 50 pounds but the volume of material is almost always more than one cubic foot. The average is more nearly 1¼ cubic feet. Therefore, if the cement and lime are proportioned on a volume or cubic foot basis, the actual quantity proportions may vary over a considerable range.

There remain two possible methods for avoiding such probable variations. One is to weigh the cement and lime but this usually is not convenient on the average job. A second and simpler procedure is to proportion by bag ratios. On this basis, a 1:1:6 cement-lime mortar is prepared by mixing the materials in the ratio of 1 bag of Portland cement, 1 bag of hydrated lime and 6 cubic feet of sand. Likewise, a 1:2:9 mortar would contain these same materials in the ratio of 1 bag, 2 bags and 9 cubic feet, respectively. Mortars thus proportioned always contain cement and lime in the same weight ratios. In fact, this is the manner in which most contractors proportion on the job. If the higher proportions of lime designated in the A.S.A. code for A, B, and C mortars are used, the ratios of cement to lime become bag ratios.

Masonry Cement Mortars. The A.S.A. code requirements previously quoted include also the recommended classifications and requirements for mortars made from masonry cement. The volume of aggregate in the mortar should be at least two times, but not more than three times the volume of the masonry cement. If and when lime is used along with the masonry cement, the combined quantity of the two is used as the total cementitious material content for calculating the quantity of sand required.

Preparing and Mixing Mortars. In order to obtain the best quality mortar, the cementitious material must be completely and uniformly mixed with the sand and thoroughly wetted. Practically all

mortars are improved by longer mixing and for these reasons, machine mixing is to be preferred over hand mixing. If the mortar is mixed by hand, a watertight box should be provided so that there can be no loss of the cementitious paste. A box of the general dimensions as that described for slaking lime (see Chapter I) is convenient. Whenever possible, best results will be obtained by thoroughly mixing the dry cementitious materials and sand before the water is added.

In many localities, ready mixed mortars are available from plants where the materials are accurately proportioned and thoroughly mixed by machine and from which the mortar is delivered to the job ready to use. Truck-mounted, portable mixers also are available. These can be located so that the mortar is available on the spot. Many contractors provide central mixing plants for the larger jobs such as commercial buildings, highways, etc.

PROPERTIES OF MORTARS

The properties of mortars which must be considered in the effort to produce a good job of finished masonry are consistency, workability and plasticity, water retentivity, extent and strength of bond, constancy of volume, freedom from staining and efflorescence, strength, flexibility, durability, and appearance. In most instances, mortar materials which meet the standard specifications when properly proportioned, will yield mortars with satisfactory original properties. All other conditions being equal, such mortars, when placed in accord with good workmanship, will produce a very satisfactory unit masonry. All of these properties are closely interrelated and will be found to a degree in all mortars. It is true that some constituents contribute more of certain of these properties than do others and some of the properties may be improved at the expense of others. It is necessary, therefore, to consider all the properties in connection with the requirements of the particular job. The importance of each property and its relation to the others and to the finished masonry cannot be discussed in detail here but the more pertinent facts will be stated.

Consistency. The consistency of a mortar refers to its degree of "wetness" and may be defined as that state or condition of the mass of mortar which varies with the water content. Different mortars may require different proportions of water to produce the same degree of

wetness and the desirable consistency may depend on the use requirements. The consistency is closely related to the ease of handling and placing of the mortars and the decision as to the amount of water used in mixing the mortar and the final consistency is usually left to the judgment of the mason. In general, the amount of water used should be the maximum consistent with good workability.[10] A large proportion of failures of mortars probably can be attributed to the use of a batch which was too stiff. Two different mortars adjusted to the same apparent consistency may differ widely in their workability characteristics. In general, the more plastic mortars possess good workability and may be easily placed when having a consistency at which they appear less wet than the harsher or nonplastic mortars. Variations in water content do not affect the apparent wetness or consistency of a plastic and workable mortar anything like as much as the same variations affect harsh or nonplastic mortars. The latter usually possess a critical point of wetness beyond which further small additions of water will produce a sloppy mortar. One of the important advantages of the highly plastic mortars of high water retentivity is that they can carry and hold larger percentages of water and still be handled conveniently.

It is obvious that sufficient water must be used to yield a mortar which can be handled with relative ease and which will readily cover all the mortared surfaces of the structural units and fill all the joints. In particular, the consistency must be such that the head joints can be shoved without too much effort on the part of the mason. It is thus much easier to fill completely all of the vertical as well as the bed joints and watertight masonry is obtained with appreciably less effort.

The generally accepted laboratory method for measuring the consistency of mortar involves the use of an instrument called the flow table. A pat of the mortar of controlled dimensions is placed on the plate of the table and the plate is raised and then dropped onto a rigid base a specified number of times (standard test is ½″ drop, 25 times). The final diameter of the pat is then measured and the consistency is recorded as the percentage increase which resulted from the impacts. For example, if the diameter of the original pat was 4″ and the final diameter 8″, the flow, or consistency, is 100 per cent. The present specifications define the flow or consistency as standard

or normal for testing purposes when the range is between 100 and 115 per cent. The average range of flow values of mortars as used on the job is generally somewhat higher, probably approximating 120 to 130.

Workability and Plasticity. By the term workability is meant the relative ease of handling. This property is influenced by most of the other characteristics of the mortar, particularly by the water retentivity, the flow or consistency, and the resistance to bleeding and segregation. These characteristics, in turn, are affected by the properties of both the cementitious materials and the aggregate and by the proportions of the two. This property of workability is frequently called plasticity. The more plastic and workable mortars are easier to mix to a uniform composition, are readily handled with the trowel but slip from the trowel without any special effort, and are easily spread on the brick to a uniform thickness; they make it easy for the mason to shove the structural units into place so that they are properly bedded in the desired position and so that the head joints are all completely filled; the mortar hangs to the units and does not fall off to stain the wall below and the losses are reduced as a result of the decreased amount of droppings; the contact and bond of mortar to the structural unit is continuous and complete and the mortar joint therefore is watertight and durable. Thus, the more plastic mortars are more economical in time and materials and yield the best finished job.

Owing to the fact that this plasticity is a manifestation of the total result of the effects of several different factors and hence quite complex, it is difficult to measure quantitatively. On the job, the well-trained and experienced mason must be the judge of the relative workabilities of the mortars. In the testing laboratory, various methods are used to measure relative workabilities. One of the later and perhaps the best method, employs the extrusion energy machine* which measures the force required to extrude the mortar through an orifice. The more workable mortars require less force to extrude the same amount of material.

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* Developed by Professor Walter C. Voss, Head, Department of Building Engineering and Construction, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Water Retentivity. The water retentivity of a material is a measure of the tenacity with which it holds on to water. This is a very important property of mortar because it affects almost all of the other characteristics. Its meaning and significance can best be explained by a description of the method by which it is measured in the laboratory. In this test, the mortar is mixed to the desired consistency as measured by the flow table (previously described) and is then subjected to suction for a fixed length of time. The consistency is then measured again on the flow table. The flow after suction is always less than before suction because some water has been sucked out, leaving the mass stiffer than before. By dividing the value found for the second flow by the value of the initial flow and multiplying the resulting figure by 100, the water retentivity value is obtained. For example, if the flow of the mortar before suction was 100 and the flow after suction is 90, then the water retentivity value is $90/100 \times 100$, or 90.

This test simulates the action of a brick on the mortar. Every mason is familiar with the fact that when mortar is placed on a porous brick it may become rigid or stiff in a short time owing to the fact that the brick absorbs some of the water from the mortar. The more porous and absorptive the brick, the more rapidly does the mortar stiffen. The mortars which possess the highest water retentivity offer greatest resistance to the suction of the brick and, for that reason, stiffen more slowly than those having lower water retentivities. The water retentivity of the mortar, therefore, must be great enough that it will remain soft and plastic long enough for the mason to properly bed the brick. A mortar with low water retentivity will stiffen before the brick can be adjusted to its final position and the resulting brick-mortar bond is likely to be incomplete and the joint sufficiently open so that it offers little resistance to the percolation of water through the wall. If the mortar congeals too rapidly when it comes in contact with an absorbent brick, the next brick placed on or against the mortar cannot be bedded properly and will not bond with the stiffened mortar. As a result there will be a network of small canals or even sizable cracks between the mortar and brick through which water will pass unobstructed. In fact, the small capillaries tend to pull in water and when all of these pore spaces are filled with water, freezing is very likely to disintegrate and ultimately destroy the mortar joint.

An additional advantage of a plastic mortar of high water retentivity is that it remains flexible long enough to adjust itself to the stresses developed as the weight on it multiplies with the increasing height of the wall.

Brick and other structural units differ widely in their suction characteristics ranging from the highly vitrified, low-suction units to those of relatively high suctions. The National Bureau of Standards[8] over the past few years has conducted an extensive investigation of the factors involved in the production of masonry. This included a study of the results obtained with brick of different suction characteristics, the results of which are briefly summarized in the following statements quoted from a publication of the Structural Clay Products Institute.[6, 8]

> The most desirable suction rates of bricks were from 0.2 to 0.7 avoirdupois ounces per minute, both for walls of high resistance to rain penetration and to transverse loads and also for complete and strong bonding of the mortar to the units. Walls which did not leak were constructed of brick having suction rates less than 0.2 oz. However, there was a tendency for these bricks to "float" and for the walls to become distorted by the bricks moving out of position, thus delaying construction. Usually floating was not troublesome when there was no surface water on the brick. An exact control of the suction rate was not necessary. The masons easily judged when the bricks were too wet. Perhaps the most satisfactory method for wetting highly absorptive brick is to spray them in a pile until water flows from all portions, several hours prior to use. As the more absorptive units tend to absorb water more rapidly than those of low absorption, the spraying may tend to produce uniformity in the suction rate. In any event the spraying will have the effect of retarding the overall suction rate of the bricks.

The best range for brick suction rate is between 0.17 to 0.71 oz. (5 to 20 grams) per minute. It is considered good practice to wet bricks which have a suction rate above 1.4 oz. (40 grams). In general, a mortar with relatively high, rather than low, water retentivity is better suited for use with units of a wider range of suction rates. Some specifications fix a lower limit of 70 for the water retentivity value but it will be found that, in general, a mortar with a retentivity of 85 will give better results in all respects.

Water retentivity values are an indication of the relative workability of most mortars, the mortars of higher retentivities usually being the more workable.

Extent and Strength of Bond. The degree of completeness of the bond between the mortar and the structural units is an extremely

important consideration in the quality and durability of unit masonry. An incomplete bond offers less resistance to water penetration and can be such that the wall will leak when exposed to rain above ground or to soil moisture if below grade. In addition, a complete bond between brick and mortar assures sufficient wall strength to resist all the lateral stresses imposed by high winds or other forces.

Relation of Properties of Mortars to Watertightness of Masonry. This watertightness of unit masonry has been mentioned several times previously, but is sufficiently important to merit additional emphasis. One of the primary purposes of a structure is to provide protection from the elements and if a wall leaks, all the expense and effort of building is lost. All of the common mortar and brick are for all practical purposes, impervious to water and any leakage, therefore, must occur at the interface between the brick and mortar.

Assuming proper design, good workmanship, and adequate inspection during construction, the most effective method of preventing wet and leaky walls is to lay up the masonry with bricks of the best suction range and with a mortar having those properties which will permit the mason, with little effort, to completely fill all joints and to so bed the brick that the maximum extent of bond can be attained.[8] That mortar should be selected which is best adapted to the particular use requirements and which will endure longest under the particular conditions of exposure. It is fortunate that in the majority of cases properties such as high water retentivity and good workability, which are desirable for use with one type of masonry unit, are equally satisfactory for all other types which have suction rates below the limit previously specified. Such mortars are readily available and, when all factors are considered, their use almost always results in economy in cost of both materials and labor. The manufacturers of mortar materials and their trade associations are always in a position to supply literature without cost which gives all the information required relative to the selection, preparation, and use of the proper mortars for the specific conditions of the job in order that the most satisfactory finished masonry can be obtained. The situation relative to masonry is similar to that of all other problems, namely, that the best is usually the easiest to obtain and most frequently the cheapest in the end.

In applying mortar, best results will be obtained by spreading it on the units rather than by deeply furrowing the bed joints.[8]

Constancy of Volume. Practically all construction materials expand or contract slightly owing to temperature changes, alternate wetting and drying, shrinkage due to loss of water, or from the results of chemical changes.[6] These facts must be taken into consideration in the design of a structure and in the selection of materials. Fortunately, the volume changes to which good mortars are subject are not sufficient to produce undesirable effects in the masonry if proper precautions are observed in their use and if the building design is correct. One of the reasons for shrinkage, for example, is the use of too little sand. Although richer mortar is usually stronger than leaner mortar in structures which are not exposed to alternate wetting and drying, it is subject to greater volume changes under conditions of severe exposure. It is for this reason that exterior stucco is made with larger proportions of sand in order to obviate any possibility of shrinkage cracks and crazing. Care must be exercised not to over-sand the mortar and thus produce a harsh, nonplastic material with which it is difficult or even impossible to do a creditable job.

Leaky masonry is always subject to greater volume changes during alternate wetting and drying and particularly during freezing and thawing because water expands enormously on freezing and this expansion produces exceedingly high stresses which tend to disintegrate the masonry. So, it is obvious that every possible provision should be made in the design and construction of unit masonry which will be exposed to freezing, that the possibility of saturation with water be reduced to a minimum.

Freedom from Staining and Efflorescence. Everyone has seen occasional examples of white scum (efflorescence) or objectionable staining on masonry. This condition is usually caused by the presence of certain soluble salts in the mortar, brick, or water, and is exaggerated by wet walls. It may be obviated by the selection of the proper materials and by correct design and good workmanship. All reputable manufacturers produce only those mortar materials which will not be subject to scumming when properly used and all job specifications should require such materials. They are readily available in all localities and usually at no greater cost than the undesirable materials.

Strength. Cases are rare of masonry failure resulting from mortars which were too weak. Assuming good workmanship, no difficulties should be encountered from insufficient mortar strength if the proper mortar is selected for the specific conditions of exposure and load. The minimum strength requirements for mortars of different composition are specified in the building code of the American Standards Association and the matter of the selection of the mortar for the particular job requirements is discussed in succeeding pages.

Flexibility, Extensibility, and Elasticity. For a discussion of these properties of mortars and masonry, no better reference can be offered than to quote the following passages from the booklet on mortar published by the Structural Clay Products Institute.[6]

> Extensibility or flexibility of a mortar specimen is the amount per unit length that the specimen will elongate before rupturing in tension. . . . High lime mortars used in masonry may result in greater plastic flow than low lime mortars, which acts with the extensibility of the mortar to impart some flexibility to the masonry, thus permitting it to take up slight movements without apparent joint opening. This resilience (flexibility) is particularly desirable in chimney construction where a mortar in the proportion of 1:2:5 (cement-lime-sand) is generally specified.
>
> The variation of extensibility for all mortars is so slight that this property, as defined, is apparently of minor importance as a specification requirement in mortars for clay products masonry.

Durability. The fact that masonry is usually selected as the type of construction used for permanent buildings is evidence of its general durability. "The importance of weather resistance of a mortar will depend upon the exposure of the masonry and the type of construction in which it is used."[6] The durability of a mortar is not necessarily a function of its strength, evidenced by the fact that recent tests have indicated that some of the newer, modified-type cementitious materials of lower strength offer greater resistance to freezing and thawing. If the mortar is highly plastic and workable so that the structural units can be well bedded with complete extent of bond, the durability of the structure then becomes a function chiefly of design and workmanship.

Appearance. Since the possibilities of masonry are so numerous and varied in respect to appearance, this property is one of interest and importance and one which should be considered in design and construction details. The variety of shape and color of available struc-

tural units such as brick, tile, stone, concrete block, terra cotta, etc., offer innumerable possibilities of combination, arrangement, and color schemes. This, together with the variety of mortar colors available, makes it possible to select a design compatible with almost any requirement of utility and yet obtain a finished structure which of itself is pleasing in appearance and which will fit into and harmonize with almost any environment. All details of location, personal tastes and desires, as well as the use requirements of the proposed structure should be made available to the architect. If no architect is employed, all these factors should be considered in preparing the original design in order that all requirements may be fulfilled. The extreme flexibility of masonry in this respect makes this possible with little added effort or cost.

Unlike many other types of construction, the appearance of properly designed masonry structures usually improves with age. Since permanence of structure and appearance may be anticipated, there is little reason for not giving thought to the attainment of a beautifully finished job while the structure is being planned. The owner will be repaid amply for this effort by the wholesome satisfaction in the pleasing result.

SELECTION AND APPLICATION OF MORTARS

If the job specifications will require that all materials to be used shall meet standard specifications, the problem of selection of the cementitious materials then becomes a matter of the local situation relative to availability and costs. It should be remembered also that the first cost of the materials is not the only consideration. As a rule, the better the materials, the lower is the labor cost. For example, materials which will yield a highly plastic, readily workable mortar may cost slightly more but may result in a lower over-all cost because the time and effort expended by the mason in laying the units with this better mortar may be sufficiently less to more than offset any increased material costs. The quality of the finished masonry, also, is more likely to be much better. A further important consideration is the cost of repairs to defective masonry. This is always high, usually recurrent, and in most instances it is almost impossible to accomplish a satisfactory result by the repair of defects in the original masonry.

In selecting the particular proportions for the mortar materials, it should be emphasized that the desirable properties of the mortar should be evaluated in terms of the use requirements. It will be noted that four types, with respect to proportions, are included in the Masonry Code of the American Standards Association.[7] The problem of selecting the particular mortar from among these to meet the specific use requirements is answered by the same code which is quoted as follows:

2-16. Type of mortar required. Masonry shall be laid in Type A, Type B, or Type C mortar, except as follows:

(a) Type A mortar shall be used in nominal 10″ cavity walls, foundation walls of hollow masonry units, and the masonry linings of existing masonry walls.

(b) Type A or Type B mortar shall be used in footings, foundation walls of solid masonry units, isolated piers, load-bearing or exterior walls of hollow masonry units, hollow walls of masonry, and cavity walls exceeding 10″ nominal thickness.

(c) Type D mortar may be used in solid masonry walls, other than parapet walls or rubble stone walls, not in contact with the soil and not less than 12″ thick nor more than 35′ in height, provided the walls are laterally supported at intervals not exceeding 12 times the wall thickness.

(d) Gypsum partition tile and block shall be laid in gypsum mortar. Nonbearing partitions and fireproofing of structural clay tile may be laid in gypsum mortar. Firebrick shall be laid in fire clay or air-setting mortar, but fire clay is preferred.

(e) Glass block, when laid in mortar, shall be laid in Type B mortar.

Contributions of Mortars to Finished Masonry. Most of the properties which mortars contribute to the characteristics of the finished masonry have been mentioned previously in various connections but some of these will bear further emphasis. In the first place, mortar is used to provide a uniform bearing or bedding for the structural units and to bind these units into a continuous, watertight mass of such strength and durability that the structure will continuously support the maximum vertical loads and lateral stresses to which it is subjected under the specific conditions of use. At the same time, it should present a pleasing appearance and possess all the aesthetic attributes of a work of art. A properly selected mortar will contribute to all these qualities.

As previously stated, watertightness and durability are primary requisites and the more plastic and workable the mortar, the easier it will be for the mason to produce a structure with these characteristics. The thickness of the mortar joints and the color of the mortar

can be so selected that they add much to the final effect. Different methods for striking or tooling the joints also may be used to modify the general appearance. A wide range of selections of mortar joint types are available but it should be emphasized that care must be exercised in selecting the type and in the actual finishing of the joints if the best results are to be obtained. This subject is well presented in the following discussion quoted from page 88 of the book, *Brick Engineering:* [6]

317. Exposed Joints. Joint thickness affects to some extent the strength of the wall. Although no definite relationship has been proven, walls with thin joints tend to have a somewhat higher strength. For standard brick, a ½″ joint is most useful in forming patterns and bonds, since the width of two headers plus the joint exactly equal the length of the stretcher.

The color, section and texture of joints will affect to a marked degree the interest and quality of the finished wall. Color of the joints should be kept uniform despite the gradations in the brick shading. Dark colored mortar tends to subdue shadows and deepens the tone of the wall. Light or natural colored mortar gives a play of brilliant shadows.

Texture of the joint may resemble that of the brick or contrast with it, and is controlled by the use of a steel or wood surfacing tool, and the use of coarse sand or fine gravel in the mortar mix. Tooled joints which compress and spread the mortar after it has set slightly, produce the best weathering properties.

(1) Weathered Joint. This is formed as a plain cut joint, finished with the trowel after the mortar has slightly stiffened. Each course of brick will throw a horizontal line of shadow along the wall. It is a water-shedding, low-cost joint, much to be preferred over the struck joint.

(2) Flush Joint. This is formed by cutting surplus mortar from the face of the wall. If a rough texture is desired, the joint must not be manipulated with the trowel. For an extremely rough joint, the surface may be tapped with the end of a rough cut piece of wood after the mortar has slightly stiffened.

(3) **V** Joint. This is similar in method of forming and performance to the concave joint. It should be formed with a special tool, but may roughly be made with a square-edged board, rubbed at an angle along the joint.

(4) Concave Joint. This is perhaps the best joint and is formed with a special tool or a bent iron rod. It is weather resistive and inexpensive.

(5) Struck Joint. This is the most simply formed of all joints and is widely used for interior walls. Its use for exterior walls is not recommended, however, because its weather resistive qualities are distinctly inferior to the other joints described.

The joints should be finished only when the mortar is in the proper condition. This should be done after the mortar has set or stiffened to such an extent that it offers appreciable resistance to

impressions by the thumb nail and yet it must be sufficiently plastic that the pressure of the jointing tool will force the edges of the mortar into firm contact with the brick. The outside edges of an originally nonplastic mortar will tend to slump away from the top brick and should be forced back into contact by the jointing tool so that openings will not be left between brick and mortar to permit water penetration. A more plastic mortar will not slump appreciably and has this important advantage. Care should also be exercised not to tool the joint to such an extent that the face is completely sealed; otherwise, any water which may have penetrated the structure cannot readily escape by evaporation. And as pointed out in the foregoing quotation, the shape of the finished joint should be such that it will not tend to collect water but will shed it readily.

Precautions in the Selection and Application of Mortars. It is well, perhaps, to recapitulate briefly the precautions which should be observed in the application of mortars in order to assure a satisfactory finished job of masonry. The use of satisfactory structural units and proper design are assumed.

The mortar should be plastic and easily workable, and the maximum amount of water consistent with good workability should be used. The type of mortar selected and the proportions should be determined by the use requirements.

All mortar joints should be well filled with particular attention being given to the vertical joints. All spaces between wythes should be filled with mortar. A good practice is to plaster the inside face of one of the adjoining wythes.

The mortar should be applied and spread, not deeply furrowed, and the units firmly pressed into position so that the maximum extent of bond and complete contact with the structural unit will be assured.

Care should be exercised in tooling the joints to prevent sealing the surfaces so that the edges of the mortar will be forced firmly into contact with the units. The shape of the finished joint should be such that it will readily shed water.

The outside of all walls below ground level should be pargetted with a coating which is impermeable to water. Likewise, the inside of all structures designed for holding water should be plastered with a dense mortar.

During construction the tops of all walls should be covered to protect them from rain.

Special Mortars. Special mortars are necessary for some types of construction depending upon the use requirements of the structure.

Stone Masonry. The only special requirements for the mortars for bedding building stone is that they shall be nonstaining. The majority of the standard mortar materials will yield nonstaining mortars but a few manufacturers produce special mortars for this purpose. Relatively thin mortar joints are usually used in stone masonry.

Industrial Chimneys. The stresses imposed on tall industrial stacks or chimneys are such that some flexibility in the structure is desirable to permit it to take up slight movements without producing openings in the joints. A 1: 2: 5 (cement-lime-sand) mortar is frequently specified for this use.[6]

Fireplaces. Ordinary masonry mortars are not sufficiently heat-resistant for this use. They tend to lose their strength when subjected to cycles of heating and cooling with temperature rises above 480° F. If masonry is to stand these higher temperatures, backup refractory bricks should be used in the areas exposed to the heat and these should be set in a cold-set refractory cement. These are fire-clay mortars which develop their maximum strength at about 900° F. and their strength improves with increase of temperature.

Stucco. Stucco may be defined as that type of coating produced by the application of a mortar over the surface of walls in a manner similar to plaster. The term is usually limited to reference to exterior coating, while plaster usually refers to coating on interior surfaces.

The use of stucco offers a great variety of pleasing and effective surface treatments with the one material.[9] A wide selection of textures can be produced with equal facility by the stucco craftsman and it is possible to adapt these to various architectural styles. A wide selection of colors makes possible the incorporation of additional attractiveness and charm. In addition to the possibilities offered in the use of various colors in the stucco itself, the surface is quite adaptable to painting with a variety of colors and paint finishes. The newer cement or cement-lime paints[8] are durable and attractive.

For two-coat outside stucco, a 1:1:6 cement-lime mortar is commonly recommended for the base coat. The second coat should con-

tain more sand than the usual 1:3 proportion. This coat should not be troweled any more than is necessary to secure the proper density. Over-troweling tends to bring the cementitious material to the surface and crazing and map-cracking is likely to result.

FORMULAS, PROPORTIONS, AND QUANTITIES

One cubic yard of masonry sand with the usual proportions of cementitious material and water will yield approximately one cubic yard of mortar. The amount of mortar required to lay any given number of structural units is determined by the shape and size of the units, the thickness of the mortar joints, and the type of bond. The surface area obtained will depend on the thickness of the wall. Table IV lists the quantities of cementitious materials required for mortars of different proportions. These values were determined by actual test and are the averages for several limes used with one cement and one sand. However, for general use, they are only close approximations. No such tabulation can be strictly accurate for all conditions owing to differences in cementitious materials and sands and variations in use requirements and practices. The values for masonry cement are the averages found by tests of five masonry cements. Weight of one bag of Portland cement is assumed to be 94 lb., of hydrated lime, 50 lb., and of pulverized quicklime, 80 lb. The weight of masonry cement is printed on the bag. One cubic foot of damp, loose sand as used on the job is assumed to contain 80 lb. of dry sand. The ratios of cementitious materials are on the bag basis. In the case of the B and C cement-lime mortars, this gives the same ratios of cement to lime as the highest ratios of lime specified for mortars of the particular types in the A.S.A. code. The 1:4:15 ratio is the one commonly used on the job for the preparation of type D mortars.

Table V gives the volume of mortar required for laying-up brick structures of different thicknesses. Table VI shows the volume of mortar required for 1000 masonry units. These values are based on an average mortar but it should be remembered that the losses resulting from droppings will be appreciably less with a highly plastic, readily workable mortar than with one which is less plastic. Data for estimating numbers of masonry units and the corresponding volume of mortar required for specific wall areas are given in Tables VII to X.

TABLE IV. ESTIMATING THE QUANTITIES OF MATERIALS REQUIRED FOR ONE CUBIC YARD OF MORTAR

Type		Mortar Mix Proportions by Volume	Weight, Pounds					Volume				
A. S. A. Code Designation	Cementitious Material Designation		Cement		Lime		Sand	Cement, Bags		Lime, Bags		Sand Cu. Ft.
			Portland	Masonry	Hydrated	Quicklime		Portland	Masonry	Hydrated	Quicklime	
A	Cement-Lime	1 : 1/4 : 3 1 Bag Portland Cement 1/4 Bag Hydrated Lime 3 Cu. Ft. Sand	839		89	48	2142	8.9		1.8	0.6	26.8
B	Cement-Lime	1 : 1 : 6 1 Bag Portland Cement {1 Bag Hydrated Lime, or 1 Cu. Ft. Lime Putty 6 Cu. Ft. Sand	442		235	127	2256	4.7		4.7	1.6	28.2
B	Masonry Cement	1 Bag Masonry Cement, Type II 3 Cu. Ft. Sand		603			2230		9.3			27.9
C	Cement-Lime	1 : 2 : 9 1 Bag Portland Cement {2 Bags Hydrated Lime, or 2 Cu. Ft. Lime Putty 9 Cu. Ft. Sand	296		315	170	2270	3.1		6.3	2.1	28.4
C	Masonry Cement	1 Bag Masonry Cement, Type I 3 Cu. Ft. Sand		603			2230		9.3			27.9
D	Cement-Lime	1 : 4 : 15 1 Bag Portland Cement {4 Bags Hydrated Lime, or 4 Cu. Ft. Lime Putty 15 Cu. Ft. Sand	178		379	205	2274	1.9		7.6	2.6	28.4

For measuring sand by shovel on the smaller jobs, it may be assumed that 150 heaping shovelfuls of damp, loose sand (job sand) measured with a No. 2 square pointed shovel are approximately equivalent to 1 cubic yard. The respective equivalents, therefore, may be substituted for the cu. ft. values for the volumes listed in the last column of Table IV.

On the same basis the following approximate proportions may be assumed for the various mortars listed in Table IV.

TABLE V. MATERIALS REQUIRED FOR MIXING A, B, C, AND D TYPES OF MORTAR

Mortar Type		Mortar Mix, Proportions by Volume	Volumes Required			
			Bags of			
A.S.A. Code Designation	Cementitious Material Designation		Portland Cement	Masonry Cement	Lime	Shovelfuls of Sand No. 2 Shovel
A	Cement-Lime	1 : ¼ : 3	1		¼	16
B	Cement-Lime	1 : 1 : 6	1		1	33
	Masonry Cement	1 : 3		1		16
C	Cement-Lime	1 : 2 : 9*	1		2	49
	Masonry Cement	1 : 3		1		16
D	Cement-Lime	1 : 4 : 15	1		4	82

*When the new highly hydrated dolomitic limes are used, this 1:2:9 mortar becomes a B type under the strength classification of the A.S.A. Code, p. 15.

A more accurate means for measurement of sand is by use of the wheelbarrow. The following tabulation shows the volume capacity of standard wheelbarrows compiled from the Federal "Simplified Practice Recommendations," R105-32, October, 1932.

Designation	Description	Capacity, Cu. Ft.
S-11	contractor's steel tray with risers	3
S-12	contractor's steel tray with risers	3½
S-13	contractor's steel tray with risers	4
S-21	same, without risers	3

Many contractors use automatic or semiautomatic weighing meters for more exact proportioning of aggregates. These meters are scales which have been especially developed for weighing the aggregate for concrete on small jobs. Many specifications for public work, and some private work, demand that the aggregates shall be proportioned precisely, measurement by wheelbarrows not being acceptable. This requirement is met by weighing the sand and stone.

The platform for the scale is several inches above the ground and it is usually necessary to wheel the aggregates up a slight incline to reach the elevation of the platform. These scales are generally mounted on wheels for moving them from job to job. Before being put into use, the wheels are removed to reduce the height of the incline.

TABLE VI. ESTIMATING VOLUME OF MORTAR REQUIRED FOR 1000 MASONRY UNITS

Building Brick* ½" Joints (None on Inside Face)†		Glazed Brick* (None on Inside Face)†			Hollow Tile* ½" Joints (None on Inside Face)†				Concrete Masonry Units‡ ⅜" Joints (Includes Interior Vertical Joints)	
Position Laid	Cu. Ft. of Mortar	Size of Face in Inches	Cu. Ft. of Mortar ¼" Joints	Cu. Ft. of Mortar ⅜" Joints	Size in Inches	Position Laid	Equivalent Brick Units	Cu. Ft. of Mortar	Size in Inches	Cu. Ft. of Mortar
Stretcher (Flat)....	11.7	2¼x8	6.1	9.2	3¾x 5x12	Side	2.91	16	3½x4x12	16.6
Stretcher (Edge)...	7.9	5x8	7.7	11.6	8x 5x12	Side	5.82	31	3½x6x12	18.3
Header............	14.9	5x12	10.0	15.0	8x 8x 8	Side	6.2	25	3½x8x12	20
Rowlock...........	14.9				8x12x12	Side	11.34	35	4x5x12	22.7
Soldier............	11.7				8x12x12	End	11.34	31	5x6x12	18.2
					3¾x12x12	Side	5.67	20	5x8x12	22.7
					3¾x12x12	End	5.67	20	4x8x16	29.5
					12x12x12	Side	17.01	50	6x8x16	29.5
					12x12x12	End	17.01	35	8x8x16	29.5
									12x8x16	29.5

*Compiled from "Recommended Mortar for Clay Products Masonry," Structural Clay Products Institute.[8]

†For mortar for interior vertical joints for brick and tile add:
3.13 cu. ft. for 100 sq. ft. for mortar joint ⅜" thick, or
4.17 cu. ft. for 100 sq. ft. for mortar joint ½" thick
Values for concrete masonry units includes mortar for interior vertical joints.

‡Calculated from Table 12 of "Facts about Concrete Masonry," National Concrete Masonry Association.[9]

The following table gives the number of brick and amount of mortar required in brick walls, assuming the standard size of brick 3¾″x 2¼″x 8 inches. Three widths of mortar joints are given: ⅜″, ½″ and ⅝ inches. The quantities are for walls having a thickness of one brick in various positions. In estimating walls composed of more than one wythe of brick, the quantity of brick is obtained by multiplying the number in one wythe by the number of wythes, and the amount of mortar for one wythe is likewise multiplied by the number of wythes, to which is also added the mortar comprising the interior vertical joint between the wythes. An interior vertical joint is usually ½″ thick and amounts to 0.0417 cu. ft. of mortar per square foot of wall area.

TABLE VII.* ESTIMATING BRICK AND MORTAR QUANTITIES

Standard Brick Size 3¾x2¼x8	Wythe Thickness	Face Area of Unit in Sq. Ft.	No. Brick per Ft. Height	No. Brick per Ft. Length	No. Brick per Sq. Ft.	Brick Courses in Height	Cu. Ft. Mortar per Brick
		Including ⅜″ visible mortar joints—add ½″ interior vertical mortar					
(a) Stretcher, edge	2¼″	.2399	2.908	1.433	4.168	1.571	.0059
(b) Stretcher, flat	3¾″	.1527	4.571	1.433	6.562	1.000	.0086
(c) Header, flat	8″	.0752	4.571	2.908	13.298	1.000	.0110
(d) Rowlock, edge	8″	.0752	2.908	4.570	13.298	1.571	.0110
(e) Soldier, end	3¾″	.1527	1.433	4.570	6.562	3.189	.0086
		Including ½″ visible mortar joints—add ½″ interior vertical mortar					
(a) Stretcher, edge	2¼″	.2509	2.823	1.410	3.986	1.545	.0079
(b) Stretcher, flat	3¾″	.1623	4.363	1.410	6.161	1.000	.0117
(c) Header, flat	8″	.0812	4.363	2.823	12.318	1.000	.0149
(d) Rowlock, edge	8″	.0812	2.823	4.363	12.318	1.545	.0150
(e) Soldier, end	3¾″	.1623	1.411	4.363	6.161	3.090	.0117
		Including ⅝″ visible mortar joints—add ½″ interior vertical mortar					
(a) Stretcher, edge	2¼″	.2621	2.743	1.391	3.816	1.521	.0100
(b) Stretcher, flat	3¾″	.1722	4.174	1.391	5.807	1.000	.0147
(c) Header, flat	8″	.0873	4.174	2.742	11.448	1.000	.0192
(d) Rowlock, edge	8″	.0873	2.743	4.173	11.448	1.521	.0192
(e) Soldier, end	3¾″	.1722	1.393	4.173	5.807	3.000	.0147

NOTE.—Add interior vertical mortar joint between wythes—½″ thick per sq. ft. of wall = .0417 cu. ft. of mortar per sq. ft.

*Tables VII to X are taken from "Recommended Mortar for Clay Products Masonry."[6]

Complete tables giving quantities for all types of masonry walls now used commercially would be quite voluminous; however, it is believed that the following condensed tables can be used as a basis for estimating the material requirements for practically all types of clay products masonry.

Some variation will be found in all tables of mortar quantities. This is due to the weights per cu. ft. which have been used as a basis. Cement, lime and sand may vary some from the standard weights

used. The more accurate method of proportioning mortar is by weight. Proportions are given in the following tables by both weight and volume.

The degree of dampness and compaction of sand causes a wide range in weights per cu. ft. In these tables, the volume of loose, damp sand is considered, while the weight is that of the dry sand normally contained in that volume of loose, damp sand. Sand is generally sold by the ton, and in its usual damp condition weighs approximately 100 lb. per cu. ft. In other words, a ton of damp sand normally contains 20 cu. ft. as given in the volume proportions, but only 1600 lb. of dry sand as listed in weight proportions.

Sand is an important component of mortar whether considered from the standpoint of strength or of economy. Since the quality of sand directly affects mortar costs and characteristics, its degree of cleanliness and the desirable size and shape of its particles cannot be sufficiently stressed.

Throughout this country are deposits of what is sometimes called "bank sand." Usually these pockets of sand are easily accessible and because of this there is a pronounced tendency for builders to use this material which is so close at hand. It is an unfortunate truth that in most cases this sand is inferior in every respect. More often than not it will contain loam or other organic material which renders it unfit for use in masonry work of any kind. Even if such sand is washed and the objectionable material removed, the particle size is generally uniformly small, making the mortar made from it weak and expensive. For these reasons, caution must be observed in the selection of sand for masonry work and a choice made on the basis of the information presented in this and the following chapters.

For a large quantity of mortar, it is advisable to determine the weight per cu. ft. of the cement, lime, and sand. Trial batches should be made and the yield accurately determined.

The number of masonry units given in Tables VIII, IX, and X are net quantities. Some allowance should be made for breakage depending upon the design and construction conditions. As a general rule, approximately 2% of the net quantity is added to provide this surplus for breakage.

In estimating quantities in a brick and tile wall, a common method

TABLE VIII. SOLID BRICK WALLS IN RUNNING BOND

Sq. Ft. Wall Area	4" Wall		8" Wall		12" Wall		16" Wall	
	No. of Bricks	Cu. Ft. Mortar	No. of Bricks	Cu. Ft. Mortar	No. of Bricks	Cu. Ft. Mortar	No. of Bricks	Cu. Ft. Mortar
1	6.16	.0721	12.32	.19	18.48	.3	24.64	.4132
10	62	.721	124.0	1.86	185	3.0	247	4.2
20	124	1.5	247	3.72	370	6.0	493	8.3
30	185	2.2	370	5.6	555	9.0	740	12.4
40	247	2.9	493	7.5	740	12	986	16.6
50	308	3.6	616	9.3	924	15	1232	20.7
60	370	4.4	740	11.15	1109	18	1479	24.8
70	432	5.1	863	13	1294	21	1725	29
80	493	5.8	986	14.9	1479	24	1972	33.1
90	555	6.5	1109	16.75	1664	27	2218	37.2
100	616	7.25	1232	18.6	1848	30	2464	41.4
200	1232	14.5	2464	37.2	3696	60	4928	82.7
300	1848	21.7	3696	55.75	5544	90	7392	124
400	2464	29	4928	74.33	7392	120	9856	165.3
500	3080	36	6160	92.90	9240	150	12320	207
600	3696	43.3	7392	111.5	11088	180	14784	248
700	4312	50.5	8624	130.1	12936	210	17248	289.3
800	4928	57.7	9856	148.7	14784	240	19712	330.6
900	5544	64.9	11088	167.25	16632	270	22176	372
1000	6160	72.1	12320	185.8	18480	300	24640	413.2

NOTE.—No headers, or pattern made with blind headers. Half-inch joints completely filled, including vertical interior joints of 8", 12" and 16" walls. For estimating number of facing and backup brick in any particular type of bond, corrections should be made according to Table IX.

is to estimate the number of facing and backup brick required, and then substitute hollow tile for the backup brick according to the equivalents listed in the third section of Table VI.

For 12" and 16" walls, the estimator should keep in mind the necessity for backup brick to complete the course behind the facing brick headers unless recessed tile backing units are used. The number of such backup brick required should be deducted from the total of backup brick to be replaced with tile.

TABLE IX. CORRECTION FACTORS TO BE APPLIED TO 4" WALL, TABLE VIII, FOR ESTIMATING NUMBER OF FACING BRICK IN VARIOUS BONDS

(Add to facing brick and deduct from backup)

Type of Bond	Correction Factor
Common bond with full header every 5th course	20% or 1/5
Common bond with full header every 6th course	16.7% or 1/6
Common bond with full header every 7th course	14.3% or 1/7
English bond, alternate courses full headers	50% or 1/2
English or Dutch bond with full headers every 6th course and blind headers in intermediate courses	16.7% or 1/6
Flemish bond, alternate stretchers and full headers every course	33.3% or 1/3
Flemish bond, with stretchers and full headers every 6th course, intermediate courses with blind headers	5.6% or 1/18
Flemish cross bond, alternate courses with stretchers and headers	16.7% or 1/6
Double header and stretcher every 6th course	8.3% or 1/12
Double header and stretcher every 5th course	10% or 1/10

TABLE X. HOLLOW TILE WALLS
(Side Construction)

Square Feet Wall Area	4" Walls		8" Walls		12" Wall Bonded Each Course			16" Wall Bonded Each Course		
	No. of 3¾"x5"x12"	Cu. Ft. Mortar	No. of 8"x5"x12"	Cu. Ft. Mortar	No. of 3¾"x5"x12"	No. of 8"x5"x12"	Cu. Ft. Mortar	No. of 3¾"x5"x12"	No. of 8"x5"x12"	Cu. Ft. Mortar
1	2.1	.034	2.1	.065	2.1	2.1	.1	2.1	3.14	.131
10	21	.34	21	.65	21	21	1	21	32	1.31
20	42	.68	42	1.3	42	42	2	42	63	2.6
30	63	1.02	63	1.94	63	63	3	63	95	4
40	84	1.4	84	2.6	84	84	4	84	126	6
50	105	1.7	105	3.25	105	105	5	105	157	7
60	126	2.1	126	3.9	126	126	6	126	189	8
70	147	2.4	147	4.75	147	147	7	147	220	10
80	168	2.75	168	5.2	168	168	8	168	252	11
90	189	3.1	189	5.9	189	189	9	189	283	12
100	209	3.4	209	6.5	209	209	10	209	314	14
200	418	6.8	418	13	418	418	20	418	628	27
300	627	10.2	627	19.4	627	627	30	627	942	40
400	836	13.6	836	26	836	836	40	836	1256	53
500	1045	17	1045	32.4	1045	1045	50	1045	1570	66
600	1254	20.4	1254	38.8	1254	1254	60	1254	1884	80
700	1463	23.8	1463	47.25	1463	1463	70	1463	2198	92
800	1672	27.2	1672	51.7	1672	1672	80	1672	2512	105
900	1881	30.6	1881	58.2	1881	1881	90	1881	2826	118
1000	2090	34.0	2090	64.7	2090	2090	100	2090	3140	131

NOTE.—One-half-inch joints; full bed joint with ends of inner and outer vertical shells buttered. (No mortar in interior joints parallel to wall.)

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    i) Masonry Cement.—A.S.T.M., C91-44T; F.S., SS-C-181b.
    j) Mortar.—For Unit Masonry, N.L.A., No. 1-45; SCPI, M1-42 and M2-42; A.S.A., A41.1-1944. For Reinforced Brick Masonry, A.S.T.M., C161-44T.
    k) Tile, Clay, Load Bearing, A.S.T.M., C34-41; F.S., SS-T-341a. Non-Load Bearing, A.S.T.M., C56-41; F.S., SS-T-351a.
14. National Bureau of Standards, "Dampness in Masonry Walls above Grade," Letter Circular LC-721, April 3, 1943.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. What quantities of lime, cement, and sand are used in type B mortar?

Answer. One part lime, one part cement, and six parts of sand.

2. What the primary components of mortar are?

Answer. The primary components of mortar are the cementitious materials, the aggregate, and the water.

3. What the names are for the most commonly used cementitious materials?

Answer. The most commonly used cementitious materials are lime, Portland cement, and masonry cement.

4. What is meant by the term "bleeding?"

Answer. Some mortars have a tendency to lose water.

5. Why some hydrated lime is soaked at least twelve hours before being used to make mortar?

Answer. To enhance the plasticizing effect.

6. What benefits to mortars are experienced when air-entraining cements are used?

Answer. This type of cement improves the resistance to freezing and thawing.

7. How natural cements are produced?

Answer. By calcining limestones which contain appreciable amounts of clay.

8. What would happen to mortar made only of cementitious materials?

Answer. The mortar would shrink to such an extent that cracks would develop in the joints between the masonry units the mortar was supposed to bind together.

9. Why it is that when sand composed of very fine particles is used in mortar, more cementitious materials are necessary?

Answer. Because all sand particles must be coated with the cementitious materials and when very fine sand is used, more coating is necessary.

10. What special treatment should be given to sand which contains clay?

Answer. Sand which contains clay should be washed as a means of removing the clay.

11. How much sand can be safely used in a mortar?

Answer. Not more than three times the volume of the cementitious material.

12. If long mixing times are advisable?

Answer. Longer mixing tends to produce better mortar, hence, the longer mixing times are advisable.

13. What one of the important advantages is of a highly plastic mortar?
Answer. Such mortar will carry and hold larger percentages of water and still be handled conveniently.

14. What water retentivity values indicate as far as mortars are concerned?
Answer. Such values are an indication of the relative workability of the mortars.

15. What type of mortar should be used when laying 10″ cavity brick walls?
Answer. Type A.

16. Why it is that straight lime mortars are seldom used?
Answer. Because they stiffen and set too slowly for modern high-speed construction and because their strengths are relatively low.

17. Why a mortar having low water retentivity is unsuitable?
Answer. Because it will stiffen before masonry units can be adjusted to their final positions.

REVIEW QUESTIONS

1. What is the difference between mortar and grout?
2. Explain the functions and requirements of mortar.
3. Where did the practice of uniting blocks and slabs of stone with mortar originate?
4. Name the five general types of mortar.
5. Would lime tend to reduce segregation if used in a mortar?
6. Can all hydrated limes be added to a mortar box without preliminary soaking?
7. Does the use of air-entraining cement give mortar more or less strength than if ordinary cement is used?
8. Why is sand used in mortar?
9. Describe an ideal sand for making mortars.
10. Why are colored aggregates generally more suitable for making colored mortar than pigments?
11. What is likely to happen if mortar has too little sand in it?
12. Explain how mortar should be mixed.
13. What is meant by the "consistency" of mortars?
14. What is meant by a "plastic" mortar?
15. What is meant by the "water retentivity" of a material?
16. What are the advantages of plastic mortars having high water retentivities?
17. How can brick walls be made watertight?

CHAPTER III

Concrete Characteristics and Mixing

QUESTIONS CHAPTER III WILL ANSWER FOR YOU

1. *To what does concrete owe its qualities of being fire resistant?*
2. *Why is the cleanliness of aggregates of such great importance?*
3. *How does steel, incorporated in a concrete structure, increase its strength?*
4. *How are the correct proportions determined when mixing concrete?*
5. *What are some of the precautions to be observed when finishing concrete?*

INTRODUCTION TO CHAPTER III

One of the most interesting and important materials used in masonry construction is concrete. Its uses and applications are so many and varied that its importance for most people has been minimized through long but close association with it. However, a moment's reflection concerning the versatility of this material will assure an appreciation never before experienced.

Concrete is interesting first because of its extreme value as a building material. It is easily adapted to an infinite variety of uses in engineering and architecture. It is interesting too because of its antiquity and because it reflects so closely the lives of the people who have used it. An excellent example of this is the originality and ingenuity demonstrated by American engineers in the concrete ships constructed during World War I when the need for merchant vessels exceeded the supply from the shipyards.

This chapter will describe the most important uses and functions of concrete and will answer the inevitable questions which will occur naturally as a product of the quest for knowledge. It will tell you the kinds of concrete employed in daily use. It will give you an idea as to its strength and how this strength can be increased through the proper use of steel reinforcement. It will give you a brief history of cement and a short description of cement manufacture sufficient to provide you with a suitable background for your trade as a mason. You will learn what ingredients are used in making concrete, the tests for their purity, and the correct proportions to be used in achieving a final product having the great strength and durability it is possible to obtain. Finally, you will be told the methods for mixing, transporting, and depositing concrete and how to go about smoothing and finishing the surface.

CONCRETE—ITS VERSATILITY

Concrete is one of the most interesting of all structural materials as well as the most useful, because it is strong, durable, sanitary,

economical, and fire resistant. The upkeep cost of concrete is low and it can be made attractive in appearance. Because it is plastic when first mixed, concrete lends itself well to the construction of all types of buildings, pavements, sidewalks, and almost innumerable other objects.

On the other hand, perhaps no other structural material depends so much for its success upon the people who mix and place it. Selection of quality ingredients, accurate proportioning, careful mixing, and proper placing are essentials in the making of good concrete.

The purpose of this chapter is to explain what concrete is, how to select the ingredients, accurately proportion and mix them, and how to place the resulting mixes according to good practice. Carelessness in making concrete usually results in disappointment if not in complete failure, whereas painstaking effort always results in satisfaction and safety.

This chapter should be studied from beginning to end before any of its contents are put to actual practice in the making of concrete. Such procedure is suggested because all explanations throughout the chapter are interdependent. In other words, all explanations must be studied before the general principles of concrete making can be understood properly.

WHAT IS CONCRETE?

Concrete is a mixture of sand, crushed rock or gravel, and cement. After these ingredients have been thoroughly mixed, water is added in the proper proportion to give a mixture of the correct consistency. When concrete has been placed after mixing, it hardens into a dense rocklike mass of great strength.

The sand and crushed stone or gravel used in concrete are known as aggregates; sand is further classified as fine aggregate and the crushed stone or gravel as coarse aggregate. The fine aggregate is of varying sizes so that the smaller particles tend to fill the spaces (voids) between the larger particles. For the same reason, the coarse aggregate also is composed of varying sizes. When the fine and coarse aggregates are mixed together, the fine aggregate tends to fill the small voids between the smaller pieces of the coarse aggregate. This results in a dense, solid mass.

Water added to a mixture of fine aggregate and cement reacts with the cement to form what is called a *cement paste.* As it is mixed, either by hand or machine, the cement paste forms a coating on all particles and pieces of the aggregate. When the mixture has been placed as, for example, for a sidewalk or structural part, a chemical reaction takes place in the cement paste which causes it to harden. This hardening process binds all of the aggregate together, forming a permanent and dense mass which is known as concrete.

Fig. 1 shows a piece of concrete which has been sawed in half. As is characteristic of good concrete, the particles and pieces of aggregate are held together by the hardened cement paste.

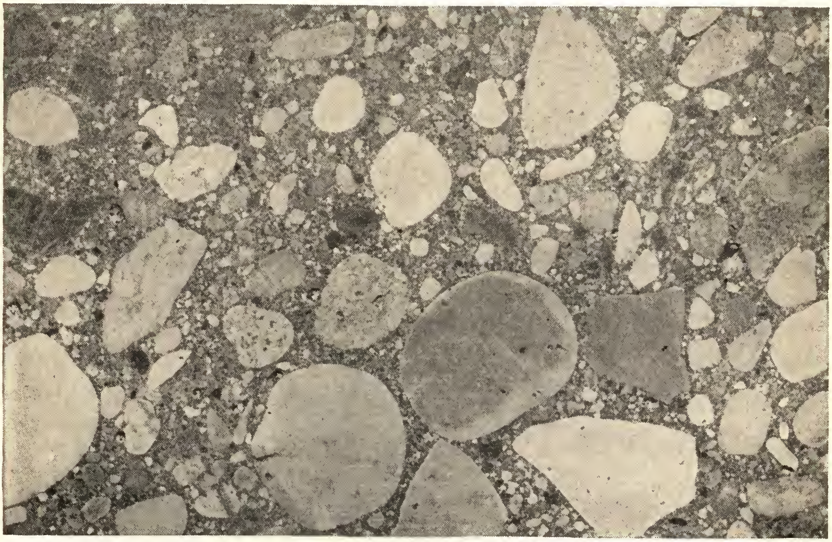


Fig. 1. Photograph of a Piece of Concrete Which Has Been Sawed in Two to Show How the Fine and Coarse Aggregates Combine to Form a Solid Mass
Courtesy of Portland Cement Association

GENERAL CONCRETE REQUIREMENTS

The two principal requirements of hardened concrete are strength and durability—strength to perform the functions the concrete is to be used for and durability to resist exposure to the elements. These requirements must be the governing considerations in the proportioning of the aggregate, cement, and water. Economy is not as important

on small jobs as either strength or durability but it becomes increasingly significant as the amount of concrete used multiplies. A fourth requirement is workability during the placing of the concrete in forms and other places. Careful proportioning and mixing of the cement, aggregate, and water will achieve the desired balance of these four requirements and the result will be a concrete mixture that is placeable in the proper degree, one that represents an economical use of materials, and one which, when hardened, will provide the necessary strength and resistance to weathering.

Good concrete should be more than strong enough to serve its intended purpose in addition to the general requirements explained in the foregoing paragraph. Concrete meeting such requirements can be made through the use of suitable ingredients, correct amounts of the ingredients, and careful mixing, placing, finishing, and curing. The direct relation between the strength of concrete and the amounts of water and cement in the mixture can be further expressed by the following rule and explanations.

RULE. *For given materials and conditions of handling, the strength of concrete is determined principally by the ratio of the amount of water to the amount of cement, as long as the mixture, when originally mixed, is plastic and workable.*

In other words, if 5, 6, or 7 gallons of water are used for each sack of cement in any mixture, the strength of the concrete is fixed regardless of the amounts of aggregates used, so long as the mixture is plastic and workable and the aggregates are clean and sound.

From the foregoing, it can be seen that the cement paste is the most important ingredient in concrete since it governs to a large extent, the strength which a concrete can develop. The strength of cement paste, in turn, depends on the amount of water used at the time of mixing. If too much water is used, the cement paste becomes thin or diluted and will be weak when hardened. A cement of this kind will not hold the particles and pieces of aggregate together and thus the concrete will be weak. On the other hand, cement paste which has just enough water in it will hold the particles and pieces of aggregate firmly together to make a strong, watertight, and durable concrete. Therefore, the ratio between water and cement must be most carefully selected

for all concrete work. In fact, concrete should be proportioned according to the amount of water to be used with each sack of cement.

In laboratory and field studies carried on by the Portland Cement Association leading to the discovery of the principle upon which the foregoing rule for the strength of concrete is based, it was found that unless mixtures were of such consistency that they could be easily molded into a dense, compact mass, the strength results did not conform to the general relationship. Also, in the studies of watertightness, it was found that unless the mixtures were easily placeable and at the same time not so fluid as to segregate in placing, no regular relationship existed between watertightness and the amount of water used in mixtures. Segregation means a separation of the coarse from the fine aggregates. True plasticity means a mixture neither too wet nor too dry. Overwet (too much water) mixtures segregate in handling and those that are too dry (not enough water) cannot be compacted properly.

As previously explained, the hardening of the cement paste results from a chemical action between the cement and water. Such a reaction takes time, the presence of moisture, and favorable temperatures. During the hardening period, a certain amount of the water in concrete combines chemically with the cement and becomes a permanent part of the concrete. To obtain plastic mixtures, more water must be used than can be combined chemically with the cement. This water will eventually evaporate, leaving voids which tend to reduce the watertightness of the concrete. Thus, no more water should be used in a mixture than is absolutely necessary for the required chemical action, strength, and plasticity.

Some structural conditions require a better quality concrete than others. For example, a concrete water tank must be watertight and stronger than an ordinary concrete footing. Because the concrete for the tank must be watertight, less water is used in making the mixture than for a concrete footing which need not be watertight. The concrete for the water tank should be made using 6 gallons of water to each sack of cement. The concrete for footings can be made using 7 gallons of water per sack of cement. In succeeding pages, more specific recommendations are given relative to the amount of water per sack of cement to use in concrete for various purposes.

KINDS OF CONCRETE

There are several varieties of concrete in terms of the quality and other characteristics of the various ingredients employed. The most important kinds are explained in the following:

Regular Concrete. Concrete composed of crushed rock or gravel, sand, and cement is called regular concrete because ordinary aggregates are used and because, generally, this kind is employed wherever concrete structural work is desired. Regular concrete is heavy, weighing about 150 pounds per cubic foot. It has great strength and durability and serves its purpose admirably. It has, in addition, the advantage of being composed of ingredients which are readily obtainable in practically every part of the country.

High Early-Strength Concrete. This type of cement, when used in the making of concrete, hardens more quickly than ordinary cement with the result that the concrete it is in develops strength much more rapidly than concrete mixed with ordinary cement. Such concrete can be used to advantage in spite of its higher cost, when floors and other structural work must be constructed and made ready for use in the shortest possible time.

Lightweight Concrete. There are many instances in structural work, especially relative to buildings, where a lightweight concrete is used to advantage. Such concrete is made from aggregates whose weight per cubic foot is considerably less than crushed stone or gravel.

CINDER CONCRETE. Concrete can be made using cinders as coarse aggregate. Generally, a mix of this kind weighs about 110 pounds per cubic foot and its use in floors, roofs, and as fireproofing material is economical in so far as total weight in a building is concerned. Cinder concrete should never be used to make beams, columns, etc. Reduced weights allow the use of lighter or smaller supports, all of which cut down on total structural costs. In localities where cinders of the proper type are available in large quantities, this type of concrete is economical to use. Blast furnace slag also can be used, like ordinary cinders, for coarse aggregate when lightweight concrete is desired.

HAYDITE CONCRETE. Haydite is a manufactured aggregate which can be used as either coarse or fine aggregate in the making of exceptionally lightweight concrete which also has insulation qualities. This kind of

concrete is suitable for most structural purposes in the same manner as cinder concrete.

Gunite. Gunite is used extensively for repair work and for reconditioning concrete in work which has become defective. It has been used for relining tanks and reservoirs, refacing retaining walls and arches, repairing concrete work damaged by fire, etc. This material is adapted to meet special work conditions. For example, where a floor must be reinforced, a steel frame may be placed under the old floor or the beams in the old floor may be reinforced and then fireproofed (fireproofing explained in succeeding pages) by the gunite method. Gunite is applied with a cement gun, as shown in Fig. 2, operated by compressed air. Special directions for operation can be obtained from the manufacturer.

Fig. 2. Applying Gunite by Means of a Cement Gun
Courtesy of Cement Gun Company, Allentown, Pa.

Rubble Concrete. Rubble concrete includes any kind of concrete in which large stones are used in the coarse aggregate. This kind of concrete is used chiefly where massive construction is involved—in building dams, retaining walls, bridge piers, etc. Rubble concrete is generally lower in cost than regular concrete because less stone crushing is required and because each large stone replaces a portion of cement and aggregate. Rubble concrete weighs more than ordinary concrete.

Before lightweight, gunite, or rubble concrete is used, a structural engineer should be consulted for the purpose of insuring proper design from the standpoints of strength and safety.

Plain Concrete. Any kind of concrete which contains no steel is called plain concrete.

Reinforced Concrete. Any kind of concrete which has steel in it for the purpose of increasing its strength is called reinforced concrete.

COMPRESSIVE AND TENSILE STRENGTH OF CONCRETE

In designing and building various structural items as foundations, footings, retaining walls, beams, etc., engineers must consider two important structural factors which are called *compressive* and *tensile* strength.

Compressive Strength. The compressive strength of concrete can be explained roughly in terms of the amount of weight or load it will support per square inch without crushing or failing. As long as a concrete sidewalk, foundation, or footing is soundly supported, the concrete will in turn safely support very heavy loads.

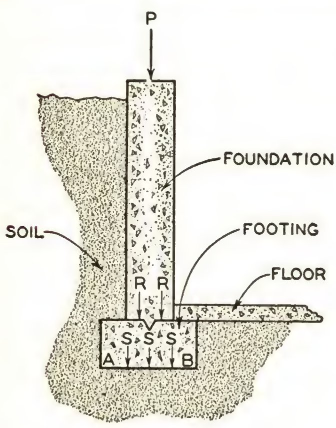


Fig. 3. Foundation for Ordinary Building Such As a Residence or Barn Showing How Wall and Floor Loads Are Supported by the Foundation, How the Footing Supports the Foundation, and How the Soil Supports the Footing

As a specific example, note Fig. 3 which shows an ordinary foundation and footing for a residence or other small building. The outside wall of the building plus portions of floor loads carried by the outside walls, are supported by the foundation. The arrow at *P* indicates such loads. The foundation is supported by the footing, and the arrows at *R* indicate how the loads from the foundation are transmitted to the footing. The footing is supported by the soil under it, and the arrows at *S* indicate how the load is transmitted from the footing to the soil. As long as the soil is firm and supports the footing uniformly along line *AB*, the footing will support the foundation soundly. Under conditions of this kind the concrete will support loads of at least 2,000 pounds per square inch. In other words, when the foundation is supported soundly, it in turn will support at least 2,000 pounds per square inch on its top surface, without crushing or failing. In this manner the foundation, by its compressive strength, is supporting heavy loads.

From the foregoing it can be seen that compressive strength means the ability of the concrete to withstand loads without crushing. If a

foundation will withstand loads of 2,000 pounds per square inch without crushing, then such concrete has a compressive strength of at least 2,000 pounds per square inch.

Tensile Strength. The tensile strength of any material can be explained roughly in terms of the material's ability to resist being broken or torn apart. Concrete, in itself, does not possess much tensile strength. Tensile strength is explained as follows:

In (A) of Fig. 4, a wooden beam spans an opening between *C* and *B*. The beam is thus supported at points *C* and *B* but has no support between *C* and *B*. Suppose that the beam supports a load, *P*, as shown.

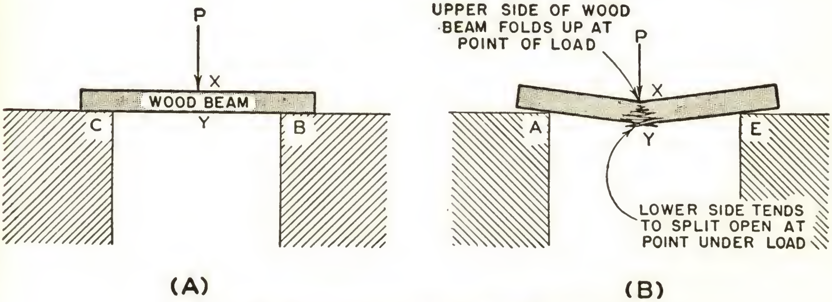


Fig. 4. The Result of Overloading a Wooden Beam

The wood beam, in such a case, must be able to resist the tendency of load *P* to break it. Or, in other words, the beam must have enough tensile strength to keep from being broken by the load *P*. Also, the beam must have enough compressive strength to prevent the load from crushing it. Note the letters *X* and *Y* in the illustration at (A). At *X*, on the upper side of the beam, the load tends to crush the beam because of its downward push. At *Y*, on the under side of the beam, the downward push of load *P* tends to stretch the beam, to break it, or pull it apart. Engineers say that there is a compressive stress at *X* and tensile stress at *Y*. This simply means that the beam must have sufficient compressive and tensile strengths to prevent the load, *P*, from crushing and breaking it.

Now suppose that the load at *P* were greatly increased. Or, suppose that the load *P* were greater than the compressive and tensile strengths of the wood beam. The illustration in (B) of Fig. 4 shows what would happen. The beam would break at the point under the load. At *X* the

wood would be crushed, and at *Y* the wood would be stretched beyond its ability to resist (beyond its tensile strength) and would be split or torn apart. From this it can be seen that tensile strength, as well as compressive strength, is important in structural design and construction.

Fig. 5 at (A) shows a concrete beam which is supported by walls at its ends *AC* and *BD*. There is no support between *AC* and *BD*. As previously explained, concrete does not have a great deal of tensile strength. This means that the load *P* could not be very great unless some means were adopted to increase the tensile strength in the beam. Without such added strength, the concrete beam would be stretched and pulled or split open at *X* under the load *P*.

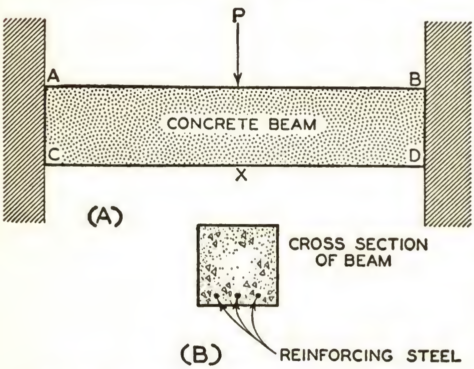


Fig. 5. Typical Reinforced Concrete Beam

Steel, unlike concrete, has great tensile strength. Therefore, if steel is put into a concrete beam at the proper place when the concrete for the beam is plastic and is

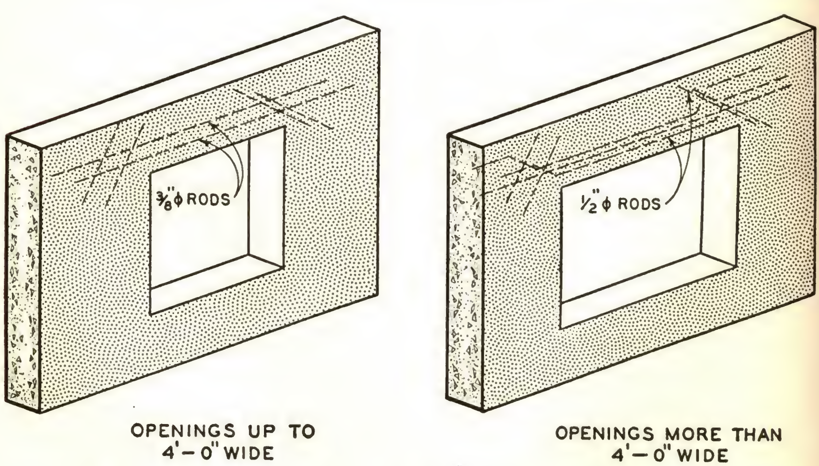


Fig. 6. Usual Method of Reinforcing Concrete Walls over Openings

being placed (poured into the forms), the beam will possess high tensile strength as well as compressive strength.

Just as for the wood beam, the tensile stress in the concrete beam is greatest near the bottom of the beam. Thus, as shown in (B) of Fig. 5, the steel, in the form of long rods, is put near the bottom. The concrete beam then has good tensile strength as well as good compressive strength.

Fig. 6 shows how rods are employed to give tensile strength to concrete over window or door openings where the concrete is unsupported.

When columns (see section view of Fig. 7) carry extremely heavy loads in large buildings, they must have steel in them because of tensile stresses which develop. An explanation of such stresses is beyond the scope of this book but the reader should know that heavily loaded columns require steel in them.

The footings, which support columns carrying extremely heavy loads, also must have some steel in them. The steel is shown in the section and plan views of Fig. 7. This footing differs from the footing shown in Fig. 3 because it supports much heavier loads and is much larger, both horizontally and vertically. The use of steel in such large footings reduces not only the amount of concrete required but also the over-all size of the footings. Furthermore, in large footings under extremely heavily loaded columns, the load is concentrated, as shown by the arrow at X in the section view. The steel helps distribute this concentrated load over the entire footing besides adding tensile strength to the concrete. Without the steel, the footing might crack or fail directly under the concentrated load even though the soil supports the footing.

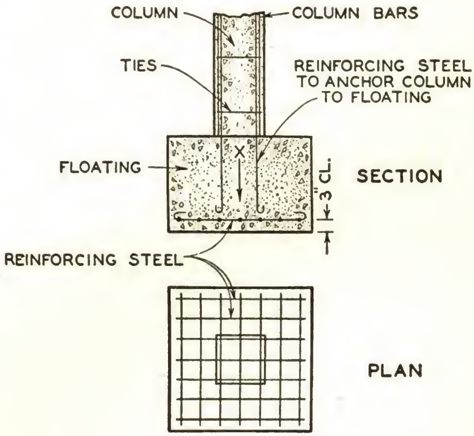


Fig. 7. When Columns Carry Extremely Heavy Loads, the Footing Supporting the Columns Must Be Reinforced by Steel Bars

STEEL REINFORCEMENT

The steel rods or bars used in reinforcing (or adding tensile strength to) concrete are usually of such shape and size that they may be bent easily and placed in concrete. To properly reinforce concrete and to secure the necessary bond between the steel and concrete, the steel must be supplied in comparatively small sections. All small types of rolled rods of square, round, and rectangular sections have been used to reinforce concrete. These rods vary in size from ¼″ for light construction, up to 1½″ for heavy beams, and up to 2″ for large columns.

Plain Rods. Plain rods, as the name indicates, look like pipes, except that they are solid. With such rods, the strength they give the concrete is dependent upon the adhesion between them and the concrete. Square and round rods show about the same adhesive strength. Round rods are more convenient to handle, are easier to obtain, and serve most reinforcing purposes satisfactorily. Flat rods do not work out well because their adhesive strength is far below that of round or square rods.

Deformed Rods. Deformed rods are rolled with ribs, lugs, or projections on their surfaces. The purpose of such deformities is to form a bond between them and the concrete, independent of adhesion. This bond formed between deformed rods and concrete is called *mechanical bond.*

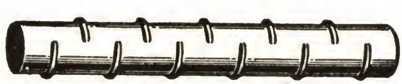


Fig. 8. Ryerson Deformed Rod

Fig. 9. Bethlehem Deformed Rod

Figs. 8 and 9 illustrate typical deformed bars of the type generally used in reinforcing concrete.

All rods used in concrete should be free from rust. This is important with regard to adhesion, especially when using plain or undeformed rods.

Cutting and Bending Rods. Most suppliers, from whom rods are purchased, have large shears for cutting the rods to the desired lengths. When no shears are available, the rods can be cut by hand using a hack saw, an oxyacetylene torch if one is in use on the job, or a hammer and chisel. Rods can be bent on the special machines which most suppliers have for that purpose, or by using a bending table and lever.

Preservation of Steel in Concrete. Structural steel and reinforcing steel when properly embedded in concrete will be preserved indefinitely. The concrete must be of sufficient thickness and density to protect the steel from moisture and air. The proof of the above statement has been confirmed many times through the razing of old structures. The steel has always been found in good condition where it was properly protected. When cracks occurred in the concrete or the concrete had been broken or destroyed, generally the steel was found to be corroded.

In steel frame buildings, the columns should be protected by at least 2″ of concrete. Some building codes require 3 inches. The beams should be protected by 1½″ of concrete on the sides and bottom, and girders by 1½″ of concrete on the sides and 2″ on the bottom. The top of the steel should be at least 2″ below the top of the concrete but 2½″ probably is better. If the top of the steel is 2½″ below the top of the concrete, there is less danger of a crack over the top of the beam and it also assists in the placing of the electric conduits.

CEMENT

Properties. When water and cement are mixed to form cement paste, the mixture is plastic for a short time, then sets (hardens) in either air or water, developing much of its ultimate strength within a few days. It is then permanent to the extent that no appreciable change in shape or volume takes place. Some shrinkage occurs in a given quantity of cement during the process of setting or hardening and there is a change in volume caused by variation in temperature. Cement mixed with sand and water is called cement mortar. When crushed stone or gravel is added to the cement and water, the resulting mixture is known as concrete. Care should be taken not to refer to concrete as cement. For example, sidewalks made of a mixture of sand, crushed stone, cement, and water should be called concrete sidewalks and not cement sidewalks.

History. It is interesting to note that cements of varying kinds have been in use since the dawn of civilization. The famous Appian Way, the great system of aqueducts, and many other structures built by the Romans were made using cement. These structures are still in an excellent state of preservation which proves the durability of cement and cement products such as concrete. An outstanding example of early concrete construction in the United States is the Horace Greeley residence at Chappaqua, New York, which was built in 1857.

The development of cement as a structural material, notwithstanding its early use, did not make much recorded progress until 1756 when an Englishman by the name of Smeaton discovered that limestone, when burned and slaked, would harden into a solid mass under water as well as in air. Other studies followed and in 1824 another Englishman, named Aspdin, perfected a method for manufacturing an improved cement which he called Portland cement because its hardened appearance resembled stone found on the Isle of Portland, Dorsetshire, England. Aspdin's method was really the first to produce a good cement and, although Portland cement has since been tremendously improved, he is given credit as being its originator.

Portland Cement. Portland cement is produced by applying great heat to argillaceous and calcareous materials, gypsum, and water until they fuse, forming clinkers. These clinkers, after cooling, are ground in ball and tube mills to a fineness allowing less than 10 per cent residue after the material has been passed through a sieve having 32,400 openings per square inch. The argillaceous material may consist of clay, shale, silica, blast-furnace slag, or slate. The calcareous material may consist of limestone, marl, oyster shell, chalks, etc. Cement is made in this country from all of these materials, each manufacturing plant using one of the argillaceous materials combined with one of the calcareous materials.

The first operation in the manufacture of cement is the quarrying of the stone and other materials. This operation is accomplished by blasting. The blasted materials are then carried to crushers. If clay or marl materials are used, they are scooped up and transported directly to the cement plant.

The next step is the fine grinding of the raw materials which may be done by the wet or dry process. In the dry process, the limestone,

clay, etc., pass from the bins in which coarse materials are stored to dryers and, after being dried, are sent to the raw grinding mill. From the grinding mill, the mixture is carried to raw mix bins and from there is fed into rotary kilns. In the wet process, sufficient water is added to the limestone, clay, etc., when they are taken from the coarse material storage bins, so that they can be ground into a creamy mixture called slurry. The slurry is then pumped to the rotary kilns.

The materials are conveyed into the upper end of the rotary kilns. These kilns are steel cylinders lined with refractory material, and are 6′ to 12′ in diameter and 125′ to 400′ in length. They are set at a slight angle from the horizontal and, as they revolve, the material feeds downward to the discharge end. The temperature in the kilns ranges up to 2800° F.

Clinkers, resulting from the action of the extreme heat, are cooled and finely ground or pulverized, then packed for shipment.

Natural Cement. Natural cement is obtained by burning argillaceous or magnesium limestone without the addition of any other materials. The resulting clinkers are finely ground and are ready for use at once. Not much of this kind of cement is made.

Low-Heat Cement. When large volumes of concrete are poured, a great amount of heat is generated in the hardening process which makes shrinkage cracks develop in the concrete. To offset such shrinking, a low-heat cement was developed which is produced by decreasing the proportion of lime and using a higher percentage of silica and iron. The lowering of the lime content reduces the amount of heat generated.

White Cement. White cement is made for use when mortar or concrete with an especially light color is desired. It is exactly like regular Portland cement except for its color.

Cement Distribution. Most cement usually is packed in cloth or paper sacks which hold one cubic foot or 94 pounds. Where large volumes are used, the cement sometimes is shipped in bulk form in freight cars.

Cement Storage. Cement is easily damaged by water and will readily absorb moisture from the atmosphere unless carefully protected. Therefore, prior to use, it should be kept in a dry place at all times.

Damaged Cement. Cement which is allowed to absorb moisture will form into lumps. If these lumps cannot be pulverized by lightly striking them with a shovel, the cement is not fit for use.

CONCRETE INGREDIENTS

Coarse Aggregates. Coarse aggregates for making regular concrete may consist of crushed stone or gravel taken from gravel banks which are found in many parts of the country.

Crushed Stone. Trap rock is the hardest and most durable stone that can be crushed and used for making concrete. This stone is dark, heavy, close-grained, and of igneous origin. Granite makes good crushed stone for concrete, and generally it is less expensive than trap rock. Hard limestone also may be crushed and used to advantage in concrete making, but it is not as strong as granite or trap rock and is affected by fire. Only the hardest grades of sandstone can be used for making concrete.

Grading Crushed Stone. In general, stone is crushed in sizes ranging from ¼″ to 2½ inches. When the stone is crushed, some of it will become much smaller than the ¼″ minimum usually considered the smallest usable size. This should be discarded or used as sand. After crushing, the stone should be screened and the different sizes kept separate or mixed together to fit the needs of various concrete mixes. When stone is crushed, the pieces should be square or triangular in shape. Flat, elongated, or thin pieces should never be used.

In concrete which is to be used for ordinary structural parts such as floors, foundations, footings, etc., the sizes of crushed stone used as coarse aggregate should be a mixture varying from ¼″ to 1¼″, or from ¼″ to 1½ inches. The smaller size is best for thin structural items. As indicated in Table I, mixtures of even smaller sized crushed stone should be used for concrete which is subject to severe wear.

For reinforced concrete members which are small and have steel rods spaced close together, crushed stone should be graded to include a mixture of pieces varying from ¼″ to ¾″ in size. This size aggregate should also be used for fireproofing structural steel. Where concrete members are larger and the steel not so close together, the crushed stone mixture may vary from ¼″ to 1¼ inches.

For concrete items which are massive, the crushed stone mixture

TABLE I. RECOMMENDED PROPORTIONS OF WATER TO CEMENT AND SUGGESTED TRIAL MIXES

Kind of Work	Add U.S. Gals. of Water to Each Sack of Cement if Sand Is			Suggested Mixture for Trial Batch		
	Very Wet	Wet	Damp	Cement Sacks	Sand Cu. Ft.	Crushed Rock or Gravel Cu. Ft.
Five-Gallon Paste for Concrete Subjected to Severe Wear, Weather or Weak Acid and Alkali Solutions						
	Maximum size aggregate ⅜ inch					
Colored or plain topping for heavy wearing surfaces and all two-course work for pavements, tennis courts, floors, etc.	4¼	Average sand 4½	4¾	1	1	1½
	Maximum size aggregate ¾ inch					
One-course industrial, creamery, and dairy floors and all concrete in contact with weak acid or alkali solutions	3¾	4	4½	1	1¾	2
Six-Gallon Paste for Concrete to Be Watertight or Subjected to Moderate Wear and Weather						
	Maximum size aggregate 1½ inches					
Watertight floors such as industrial plant, basement, dairy barn, etc. Watertight foundations Concrete subjected to moderate wear or frost action such as driveways, walks, tennis courts, garage floors, etc. All watertight concrete for swimming and wading pools, bird baths, fish ponds, septic tanks, storage tanks, etc. All base course work such as floors, walks, drives, etc. Steps, chimney caps, blocks, concrete masonry, fireplaces, etc. All reinforced concrete structural beams, columns, lintels, slabs, residence floors, etc.	4¼	Average sand 5	5½	1	2¼	3
Seven-Gallon Paste for Concrete Not Subjected to Wear, Weather or Water						
Foundations, walls, footings, mass concrete, etc., not subjected to weather, water pressure or other exposure	4¾	Average sand 5½	6¼	1	2¾	4

NOTE.—It may be necessary to use a richer cement paste in some cases. For example, a swimming pool ordinarily is made using a 6-gallon paste. However, in strongly alkaline soil a 5-gallon paste should be used.

may vary from ¼″ or ½″ up to 2½ inches. Massive items include retaining walls, extra thick foundations, etc.

Gravel. The term *gravel* refers to stone as it occurs naturally in gravel banks. Generally gravel is small pieces of stone which are somewhat rounded in shape. It makes good coarse aggregate because it is hard and close textured. Often in the past it has been the practice to use the sand and gravel directly from gravel banks for coarse and fine aggregate. This practice should be avoided because in most cases too much sand is present and the pieces of stone are not properly graded. In addition, bank-run material may contain too high a percentage of loam, clay, or vegetable matter.

Grading Gravel. When gravel is used as a coarse aggregate, the sizes of individual pebbles making up the various mixes should be approximately the same as outlined for crushed stone.

If, for example, a mixture of gravel ranging from ¼″ to 1½″ in size is required, it is not necessary that exactly equal amounts of the various sizes be used. However, the best grading, and therefore the best concrete, results when the various sizes are fairly well divided as to the quantity of each. Fig. 10 shows good concrete gravel and the variety of sizes. It will be seen that the various sizes of pebbles are nearly, but not exactly equal in amount. To secure a suitable mixture of gravel for concrete, it is advisable to screen the gravel as it comes from the bank and then mix the various sizes somewhat as suggested by Fig. 10. Good concrete just does not happen. Instead, care must be exercised in the selection of the aggregate. The use of improper aggregate always results in poor concrete and unsatisfactory structural work.

Testing Gravel for Cleanliness. Both crushed stone and gravel aggregate must be free from loam, soil, silt, or vegetable matter. This is absolutely necessary. If any coarse aggregate is covered with such foreign matter, the cement paste will not adhere to it, and very poor and completely unsatisfactory concrete will result. Crushed stone is not likely to contain any foreign material because of its being crushed from large pieces but bank gravel often does. Therefore the following tests should be made before the gravel is used:

1. Place about 2″ of representative samples of the gravel in a glass fruit jar.

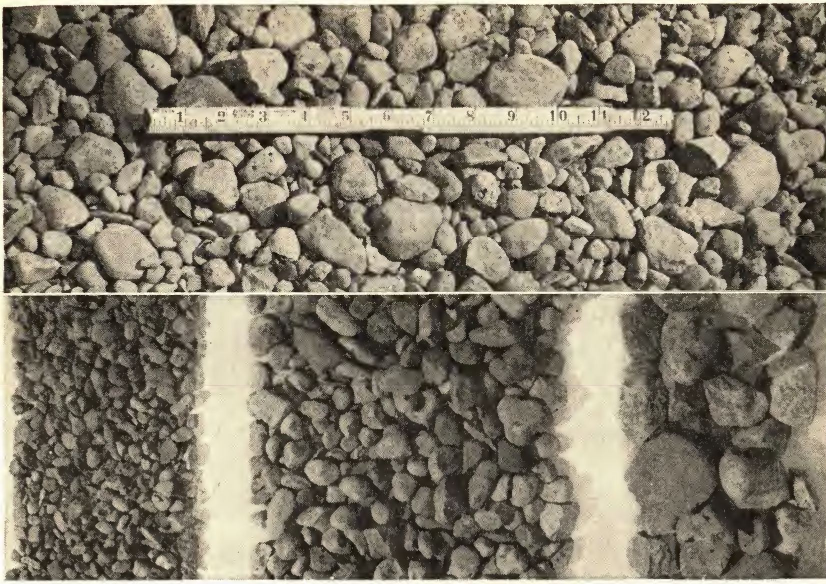


Fig. 10. Coarse Aggregate for Concrete

Good concrete gravel is shown at top. Note the variety of sizes, the smaller stones filling in spaces between larger ones. The three samples below were obtained by screening the natural mixture of gravel above. Smallest sizes are ¼″ to ⅜″; next are ⅜″ to ¾″; largest are ¾″ to 1½ inches.

Courtesy of Portland Cement Association

2. Add water until the jar is almost full. Fasten the cover. Shake the jar vigorously, then set it aside until the water clears.
3. Measure the layer of silt, etc., covering the gravel. If this layer is as much as ⅛″ thick, the gravel is not clean enough for use and must be washed.

Gravel may be tested to determine the possible amount of vegetable matter in the following manner:

1. Dissolve a heaping teaspoonful of household lye into ½ pint of water in a glass fruit jar.
2. Pour ½ pint of representative gravel samples into the jar containing the lime water.
3. Cover the jar tightly and shake vigorously for 2 or 3 minutes.
4. Set the jar aside for 24 hours and then inspect it in good light.
5. If the water is clear or not darker in color than apple cider vinegar, the gravel is suitable for use in concrete. However, if the color of the water is darker than this, the gravel should be washed before using.

Washing Gravel. Gravel may be washed to make it clean enough for use in concrete. A satisfactory washing table is shown in Fig. 11. It consists of a wide, shallow, sloping trough. The gravel should be

shoveled onto the high end and drenched with water from a hose or pail. Enough water must be supplied to wash the gravel down to the platform. This method generally disposes of foreign materials and leaves the gravel ready for use. However, the gravel should be retested after washing to make sure that one washing is sufficient.

The foregoing tests and washing may seem to be a great deal of added work, but the results justify it.

CINDERS. The cinders from the burning of bituminous coal and anthracite can be used as coarse aggregate for lightweight concrete. The cinders should be well burned and free from foreign matter and

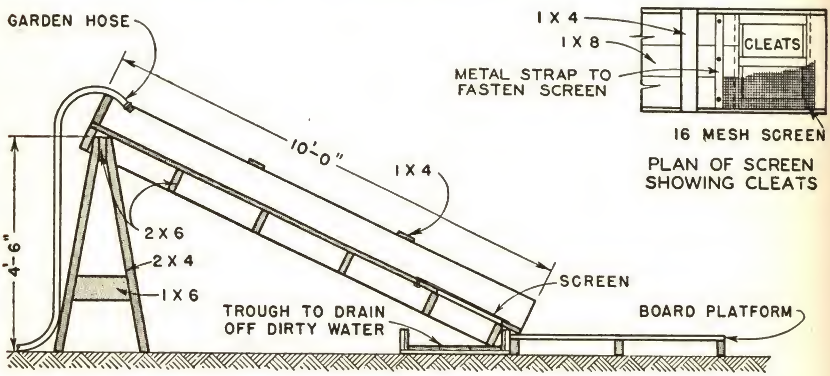


Fig. 11. Sloping Table for Washing Bank-Run Gravel

common ashes. Any large clinkers should be crushed and not more than 35 per cent of unconsumed coal should be in the cinders. Good cinders may be obtained from gas works, industrial plants, or other sources where large amounts of coal are burned at a high temperature. Cinders or ashes from small stoves or domestic furnaces are not fit for use in concrete. If cinders are dirty, they should be washed as explained for gravel.

BLAST FURNACE SLAG. Blast furnace slags are composed chiefly of silica, alumina, magnesium, and lime. Any blast furnace slag can be used as coarse aggregate if it weighs a minimum of 70 pounds per cubic foot. Such aggregate, like crushed stone or gravel, should be well graded.

HAYDITE. Haydite is made by burning shale. The product is a

lightweight cellular material weighing about 50 to 60 pounds per cubic foot.

RUBBLE. The aggregate for rubble concrete is similar to regular concrete except that from 20 to 50 per cent of the mass of the concrete is taken up by the large stones. The use of large stones in massive concrete, such as dams, is economical and satisfactory if no voids are left between them in the concrete.

Fine Aggregates. Satisfactory fine aggregates for concrete are sand and crushed stone or gravel screenings. The most important of these by far is sand.

SAND. The word sand, when used in connection with mortar and concrete, is a term applied to any finely divided material of rock or mineral origin, the particles of which have a diameter ranging from $\frac{1}{20}$ to 2 mm., which will not injuriously affect the cement, and which is not subject to disintegration or decay. Sand is almost the only material which is sufficiently cheap and which will fulfill these requirements, although stone screenings (the granulated or pulverized material resulting from stone crushing) and powdered slag have been used as substitutes.

As previously explained, sand is an important part of concrete. In fact, the strength of any concrete is dependent to a considerable extent on the qualities of sand. Improper sand could easily be the cause of concrete failure.

Sand is required in mortar or masonry for economy and to prevent the excessive cracking that would take place without it. If cement only were used in making mortar or if the cement and coarse aggregate alone were used in making concrete, cracking would occur to such an extent that their strengths would be seriously, if not completely, destroyed.

Quartz sand is the most durable and unchangeable. Sands which consist largely of grains of feldspar, mica, etc., which will decompose upon prolonged exposure, are less desirable than quartz.

Grading. The most satisfactory sand is a mixture of coarse and fine grains, with coarse grains predominating. It makes a denser, stronger concrete than does fine-grained sand when both sands are mixed with the same quantity of cement. In other words, very fine sand may be used alone but it makes a weaker concrete. In a given

quantity of very fine sand, there are more grains or particles than in the same quantity of coarse sand. More water is required to mix mortar or concrete using very fine sand. The water forms a film and separates the fine grains, thus producing a larger volume of concrete but with less density and strength.

A well-graded sand has particles ranging in size from very fine up to those which will pass through a screen having meshes ¼″ square.

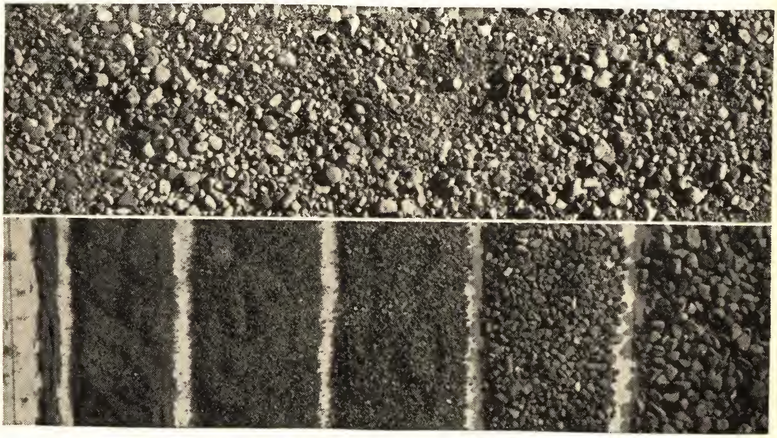


Fig. 12. Fine Aggregate for Concrete

Good concrete sand is shown at top. Sizes vary from very fine to small particles which will just pass through a ¼″ screen. The variety of sizes needed in a good concrete sand is illustrated by the six sizes below which were screened out of the natural mixture of sand above.

Courtesy of Portland Cement Association

As previously explained, the larger particles should predominate in quantity. Fig. 12 shows a good sand for making concrete. Note that the particles are of various sizes and that the larger sizes predominate. Well-graded sand not only makes stronger concrete but allows a more economical use of cement paste in filling the voids and binding the aggregate together.

The particles of sand may be either round or angular. The idea that sand should be sharp (angular) has been disproved by tests which show that there are fewer voids in round than angular sand. There is really little difference in the strengths of concrete made using sharp and round sand except that round sand helps to produce a denser mix. On the other hand, cement paste adheres to the angular sand

somewhat better than to the smooth surfaced round sand particles, so either type of sand can be used successfully. The shape of the particles is not nearly so important as their soundness and their being properly graded from fine up to $\frac{1}{4}$ inch.

Testing for Cleanliness. Like coarse aggregate, all sand or fine aggregate must be clean and free from vegetable matter. Very few natural deposits of sand, such as bank sand or the sand dredged from river bottoms, are absolutely clean and free from vegetable matter. Thus it is always wise to test representative samples of sand before it is used for making concrete. The silt test for sand is exactly the same as explained for gravel aggregate. If sand is found to contain excessive amounts of silt or vegetable matter, it can be washed in the same manner previously described for gravel.

The vegetable matter or colorimetric test is a good indicator of the presence of dangerous vegetable matter. This test is especially valuable when locating new deposits.

In making the test, an ordinary 12-ounce prescription bottle such as druggists use is filled to the $4\frac{1}{2}$-ounce mark with a sample of the sand to be tested. A 3 per cent solution of caustic soda (sodium hydroxide) is added until the 7-ounce mark is reached. (A 3 per cent solution of caustic soda is made by dissolving 1 ounce of sodium hydroxide, which may be purchased at any drug store, in a quart of water, preferably distilled. The solution should be kept in a glass bottle tightly closed with a rubber stopper. Handling sodium hydroxide with moist hands may result in serious burns. The solution is also injurious to clothing, leather, and most other materials.)

As soon as the solution of sodium hydroxide is added to the sand, the contents of the bottle should be shaken thoroughly and then allowed to stand for 24 hours. At the end of that time, the color of the liquid indicates whether the sand contains dangerous amounts of vegetable matter. A colorless liquid above the sand (see first bottle in Fig. 13) indicates a clean sand, free from vegetable matter. A straw-colored solution above the sand (see middle bottle in Fig. 13) indicates some vegetable matter but not enough to be seriously objectionable. Dark-colored liquid above the sand (see third bottle in Fig. 13) means that the sand contains objectionable amounts of vegetable matter and should not be used until it has been washed.

Moisture in Sand. Most sand contains varying amounts of moisture (water) which must be carefully considered when mixing concrete. It is essential to remember that the amount of water used in making concrete is all important. With these two facts in mind, the following explanations should be carefully studied for they are important in the mixing of good concrete.

After selecting the total amount of water (to be explained in the following pages) to be used with each sack of cement to make a

Fig. 13. Test for Silt

The colorimetric test is used to detect the presence of harmful amounts of organic matter in aggregates. A colorless liquid indicates aggregate free from organic matter. A slightly colored liquid indicates presence of some organic matter but not enough to prove injurious. A dark liquid, as in the right-hand bottle, shows that the aggregate is unsatisfactory for concrete work unless the organic matter is washed out.

Courtesy of Portland Cement Association

cement paste of the desired quality, it is necessary to take into consideration the amount of water held by the sand to be used, as this moisture is free to react with the cement and must be considered as a portion of the water going into the mix.

The degree of moisture content of sand has been standardized to some extent and is as follows:

Dry Sand: Dry sand, which flows freely, is seldom available for concrete work. It has no appreciable moisture content.

Damp Sand: Damp sand feels slightly damp to the touch but leaves very little moisture on the hands. Such sand usually contains about 1/4 gallon of water per cubic foot.

Wet Sand: Wet sand, which is the kind most usually available, feels wet and leaves a little moisture on the hands after being handled. Such sand contains about 1/2 gallon of moisture per cubic foot.

Very Wet Sand: This sand is dripping wet and leaves more moisture on the hands than wet sand. Very wet sand contains about 3/4 gallon of moisture per cubic foot. If the sand is composed mostly of very fine particles, it may contain as much as 1 1/4 gallons per cubic foot.

To learn how to *feel* sand to determine its moisture content, a simple experiment can be performed.

Spread about 2/3 of a sack of sand in a thin layer on paper, canvas, or a dry floor inside a building and let it dry. It should be stirred now and then to make sure all surface moisture disappears. When the sand feels dry and flows freely, it is ready for use.

Measure out 3 gallons of the dry sand, placing one gallon in each of three pans. Then, using a prescription bottle as a measure, add 5 ounces of water to one pan, 12 ounces to the second, and 20 ounces to the third. Mix the sand and water in each pan thoroughly.

The pan containing 5 ounces of water is damp sand; that containing 12 ounces is wet sand; that containing 20 ounces is very wet sand. These three pans of sand will teach the appearance and feel of the three moisture contents.

Water. The water used in the making of concrete should be pure enough for human consumption. If this rule is followed, no trouble will ever be encountered. It should always be remembered that impure water containing injurious amounts of oil, acid, and organic material, can ruin concrete completely.

Admixtures. Sometimes various substances are mixed with concrete to accelerate its setting, improve its workability, increase its waterproof qualities, harden its surface, etc. Calcium chloride, hydrated lime, and kaolin are the substances most generally used. The calcium chloride tends to lessen the setting time and acts as a surface hardener. Hydrated lime and kaolin render the concrete more workable. There are many waterproofing compounds on the market.

The use of any admixture should always be carried on following the directions supplied by the manufacturer or under the guidance of the Portland Cement Association of Chicago, Illinois.

PROPORTIONING CONCRETE INGREDIENTS

Not many years ago, it was customary to specify the proportions (quantities of cement, sand, and crushed stone or gravel) for regular concrete mixes by such designations as 1:2:4, 1:3:5, etc. The 1:2:4 designation, for example, meant 1 part cement, 2 parts sand, and 4 parts crushed rock or gravel. This method of specification fails to assure satisfactory results for the following reasons.

1. It does not specify the quantity of mixing water which is so essential in making strong and watertight concrete.

2. It does not consider the grading of the aggregates.

3. It does not allow for variation in volume resulting from the tendency toward bulking of moist sands.

Present-day methods of specifying regular concrete mixes are made by paying careful attention to the amounts of water, the moisture content of the sand, and the amounts of aggregates used in the mix.

Recommended trial qualities of concrete[1] and amounts of the ingredients for each, for various classes of work, are shown in Table I. This table can be used as a guide to proportioning concrete materials according to the total amount of water required with each sack of cement.

Determining Suitable Proportions. Suppose, for example, it is necessary to determine the proper mix (proportioning of all ingredients, including damp sand and water) for building a water tank. For this job, the concrete must be watertight and be able to stand severe exposure to weather.

Table I shows that for a job of this kind, a 6-gallon paste should be used. But, for a trial batch using one cubic foot (one sack) of cement, 2¼ cubic feet of sand, and 3 cubic feet of crushed stone or gravel, only 5½ gallons of water can be added when mixing the ingredients, because (as previously explained) two cubic feet of damp

[1]Recommendations by courtesy of the Portland Cement Association of Chicago.

sand will contain 2 × ¼, or ½ gallon of moisture. This ½ gallon plus the 5½ gallons makes up the total of 6 gallons required per sack of cement.

Assuming a mechanical mixer is to be used, first place the correct amount of water in the mixer. Add one sack of cement, 2¼ cubic feet of sand, and 3 cubic feet of crushed rock or gravel and run the mixer for at least two minutes. By noting how the resulting mix handles and places, it can be determined readily whether changes in the proportions are necessary to fit the needs of the job. If the concrete is a smooth, plastic, workable mass that will place and finish well, the correct proportions for the job have been determined. Fig. 14 shows at (A), a mix which lacks sufficient mortar, at (B), a mix having excess cement and sand, and at (C), a mix with good proportions. While the mix shown at (C), in Fig. 14, is good, it will not satisfy every condition. For example, it may be too stiff for use in making some concrete objects where the mix must surround reinforcing rods or run into narrow forms, etc. Thus, the particular job at hand, to some extent, governs the condition of mixes.

Correcting Trial Mixture. If the trial mix is not workable under the conditions of the job, the amounts of aggregate used in the concrete must be changed. *However, the amount of water should not, under any circumstances, be changed.* The trial batch of 1 part cement, 2¼ parts sand, and 3 parts coarse aggregate may, for example, be too stiff or too wet or may lack smoothness and workability.

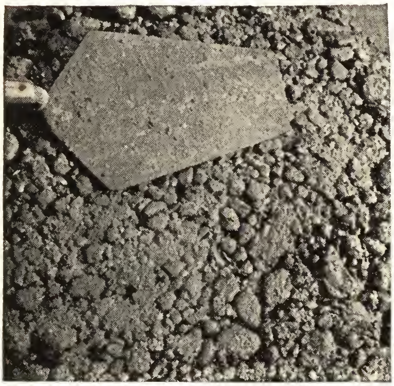
When the trial proportion gives a mixture that is too wet, add small amounts of sand and coarse aggregate in the proportion of 2¼ parts of sand and 3 parts coarse aggregate until the correct workability is obtained.

If it is necessary to use more sand than is shown in the proportions given in Table I—for instance, an extra ½ cubic foot—it is important to deduct the moisture carried by this additional sand.

If the concrete is too stiff and appears crumbly, succeeding batches can be mixed with less aggregate.

Under ordinary conditions, a concrete mix should be *mushy* but not *soupy*. The mushy mix will hold together while a soupy mix may separate in handling, with the larger pieces of aggregate sinking in the mass.

In some cases, concrete specifications still call for concrete as a 1:2:4 mix. There may be danger in following such a specification exactly, as explained in the following.



(A)

(B)

(C)

Fig. 14. Three Possible Conditions of Concrete Mixtures

Concrete mixture which lacks sufficient mortar (*left*), concrete mixture having excess cement and sand (*right*), and concrete mixture having correct proportions (*below*).

Courtesy of Portland Cement Association

Suppose that a 1:2:4 mix is specified and that the sand available for use is average in regard to moisture. First of all, unless the approximate amount of moisture in the sand is determined, the cement paste will be diluted. In addition, sand of average moisture content is bulked

at least 20 per cent because the moisture forms a film around each sand particle and thus forces the various particles farther apart. If such bulked sand is used in a 1:2:4 mix, the resulting concrete will be 20 per cent short on sand and will detract from the strength and density of the concrete. To overcome this shortage, a mix of 1:2¼:3, as recommended in Table I, or 1:2½:3½ should be used. This might result possibly in some oversanding, but that condition would be much better than undersanding.

Making Economical Concrete. From the standpoint of economy, especially on large jobs, it is usually desirable to get as much concrete per sack of cement as possible. In making concrete, the expensive ingredient is the cement. Thus, the more aggregate mixed with the cement paste, the more concrete produced per sack of cement. It is obvious, then, that the stiff mix produces the most concrete per sack of cement. Under such conditions as making walks, drives, and footings, stiffer mixes than the standard mushy consistency are perfectly acceptable if they are plastic and workable, if they can be placed properly, and if all aggregate is adequately coated with the cement paste. Such stiff mixes should not be so heavily aggregated as to look like the mix shown at (A) in Fig. 14. This mix will produce a honeycombed concrete with rough surfaces.

Cinder Concrete. When cinder concrete is to be used, the proportioning should be about 1 part cement with 2 parts sand and 4 or 5 parts cinders. Water is proportioned as per Table I.

Gunite. The recommended proportioning for Gunite is 1 part cement to 3 parts sand with water proportioned as per Table I.

Haydite. The recommended proportioning for Haydite when it is used as a coarse aggregate is an amount of sand or fine Haydite nearly equal in volume to the coarse aggregate. The complete specification is 1 part cement to 2 or 3 parts of fine Haydite and a like volume of coarse Haydite. Water is proportioned as per Table I.

Rubble. Regular concrete of 1:2¾:4 proportions generally is used where large stones are to be embedded in the mass. The mix should be more plastic, using a 7-gallon cement paste. Usually the content of large stone volume in rubble concrete is expressed in percentages of the finished work. The percentage varies from 20 to 65 and depends largely upon the size of stone being used. There is nearly as much

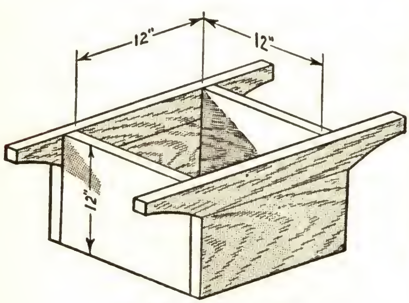
space between small stones filled with ordinary concrete as between large ones. The percentage therefore increases with the size of stones. The distance between the largest stones may vary from 3″ to 18 inches.

Building Code Proportions. The proportioning recommendations given in the foregoing and in Table I may not always agree with building codes or construction laws in various cities and towns. Therefore, the reader should always check such codes if he lives in a locality where one is in force. He should follow the code specifications unless special permission can be secured from the proper authorities, permitting deviation from the code.

MEASURING AND MIXING CONCRETE

Measuring Ingredients. While careful selection of ingredients and proper proportioning are absolutely necessary in order to make good concrete, they are not in themselves entirely sufficient. Measuring and mixing the ingredients are of equal importance. Unless careful measuring and mixing are practiced, poor concrete will result as surely as though incorrect ingredients were used.

Measuring Aggregates. Proper measuring of ingredients not only assures good concrete but guarantees uniformity for all batches mixed as well. This is important from the standpoint of placing the concrete in the forms. Aggregates can be measured, using ordinary pails, measuring boxes, shovels, and wheelbarrows.



CU. FT. BOTTOMLESS MEASURING BOX

Fig. 15. Typical Wood Measuring Box

Pails. For small batches of concrete, the sand and crushed stone or gravel can be measured by pails. For example, if a 5-gallon concrete paste (see Table I) is to be mixed, each batch will consist of 2¼ pails of sand and 3 pails of crushed stone or gravel. This is an accurate measuring method which gives good results.

Measuring Boxes. A typical measuring box is shown in Fig. 15. This box measures exactly 12″x12″x12″ on the inside and thus constitutes one cubic foot. The box has no bottom. It is placed on

the platform where hand-mixed concrete is to be made, filled with aggregate, then lifted up by the handles. In this way cubic feet and fractions of cubic feet of sand or crushed rock or gravel can be measured accurately. For example, 2¼ cubic feet of sand can be measured by filling the box level with the top twice, then once, one-quarter full.

Shovels. The use of shovels as a measuring medium easily can be inaccurate unless considerable care is exercised. One good method of judging how many shovelfuls constitute one-quarter, one-half, or one cubic foot is to count how many shovels of sand or coarse aggregate are required to one-quarter, one-half, or completely fill a one cubic foot measuring box. The people handling the shovels must be careful to include the same amount of aggregate in each shovelful; otherwise, the quality of the concrete will suffer.

Wheelbarrows. If measuring is done with wheelbarrows, each barrow should be marked on the inside for one-quarter, one-half, and one and two cubic feet. This marking can be done by first measuring such amounts in a measuring box, then transferring the amount to the barrow. The level of the material is then marked on the inside of the barrow.

MEASURING CEMENT. Each sack of cement is a full cubic foot.

MEASURING WATER. Water can be measured by the use of an ordinary 12-quart galvanized pail, marked off in gallons, half, and quarter gallons. Some cement mixing machines have automatic water measuring equipment which makes pail measuring unnecessary.

Mixing Concrete. Concrete can be mixed by hand or by the use of mixers such as shown in Fig. 16. The ingredients for each batch are put into the hopper which charges the mixer. Complete directions for the use of mixers can be secured from their manufacturers.

It is recommended that each batch be mixed for at least two minutes in order to assure good strong concrete. Reducing the mixing time results in poor concrete.

At the end of each day's run, or whenever concreting is stopped for more than an hour, the mixer should be thoroughly washed and cleaned out. This can be done easily by scouring with water and crushed stone or gravel. Any caked concrete adhering to the mixer (drum) should be broken loose and removed.

MIXING CONCRETE BY HAND. Good concrete can be mixed by hand if the following explanations are kept in mind.

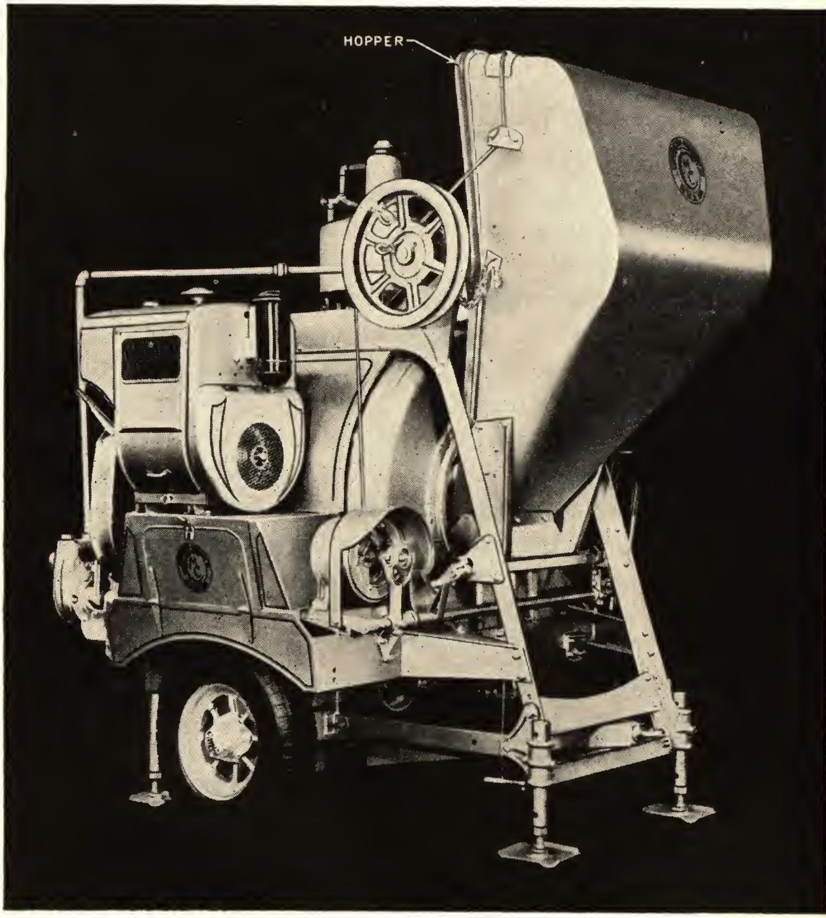


Fig. 16. Mechanical Concrete Mixer
Courtesy of Construction Machinery Co., Waterloo, Iowa

The concrete should be mixed on a wood platform or some other flat and smooth base which will not absorb water. In most cases, a wood platform such as shown in Figs. 17, 18, 19, and 20 serves the purpose to the best advantage.

Use a measuring box to obtain the correct amount of sand and spread it evenly on the mixing platform. Next dump the required amount of cement on the sand, as the workman is doing in Fig. 17, and distribute it evenly.

Fig. 17. First Step in Mixing Concrete by Hand
Courtesy of Portland Cement Association

Fig. 18. Second Step in Mixing Concrete by Hand
Courtesy of Portland Cement Association

Mix the sand and cement, preferably using No. 2 square-pointed shovels, until the mass is of uniform color and free from streaks of brown or gray. When such streaks are present, they indicate that the sand and cement are not well mixed.

Next measure the amount of crushed stone or gravel by the use of a mixing box as demonstrated in Fig. 18. The coarse aggregate should be spread over the sand and cement mix.

Mix the coarse aggregate with the cement and sand mix. The ingredients should be turned several times, using shovels as illustrated in Fig. 19, until

Fig. 19. Third Step in Mixing Concrete by Hand
Courtesy of Portland Cement Association

the coarse aggregate is thoroughly distributed throughout the mix. At least three turnings are absolutely necessary.

Make a depression or hollow in the center of the mix, as indicated in Fig. 20. The proper amount of water should be added slowly to the depression or hollow, while the ingredients are turned in toward the center with shovels. Turn the mixture until all ingredients are thoroughly combined and it has the desired workability and smoothness necessary for the job.

When concreting is finished for the day, the platform should be carefully cleaned of all concrete so as to be ready for use the following day.

PLACING CONCRETE

Under most conditions it is not advisable to move concrete, after mixing, a great distance to the point of placing. If possible, all mixing

should be done close to the forms in which the concrete is to be placed.

On small jobs, wheelbarrows are the usual means of transportation. On larger jobs, two-wheel buggies (containers having a greater capacity than wheelbarrows) are commonly used. When using barrows, care must be taken to prevent segregation of the coarse from the fine particles as the concrete is being moved. If conditions allow its use, a rather stiff mix will usually prevent harmful segregation.

Fig. 20. Fourth Step in Mixing Concrete by Hand
Courtesy of Portland Cement Association

Just as soon as concrete is mixed, it should be deposited in the forms and in no case more than 45 minutes after mixing.

Foundations. When pouring concrete into foundation forms, it should *flow* into the forms in a steady stream and not *fall* in such a way that the mixture segregates the ingredients. Deposit the concrete in continuous layers not more than 6″ to 12″ deep. As the depositing takes place, a spading tool (see Fig. 21) should be used to puddle the mix. This is done by moving the spading tool up and down in the concrete. Such action forces air out of the mix and tends to cause good settlement and a dense mass. Working the mix with the spading

tool immediately next to the forms insures an even, dense surface when the forms are removed.

If a foundation cannot be completely poured in one day's run, or where work has to be stopped long enough for the concrete to begin hardening or setting, the top surface should be roughened just before it hardens, in order to produce a good bond for the next layer of concrete. Before resuming concreting, clean the roughened surface and brush with a cement-water paste of a thick, creamy consistency. This paste should be applied just a few feet ahead of the concreting so that it does not have a chance to dry before it is covered with concrete.

When the last concrete at the top of a foundation is poured, any necessary anchor bolts should be installed. When the concrete starts to set, its top surface should be smoothed, using a trowel.

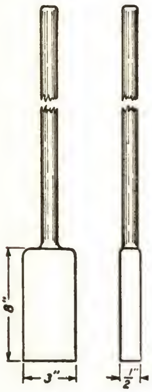


Fig. 21.
Spading Tool

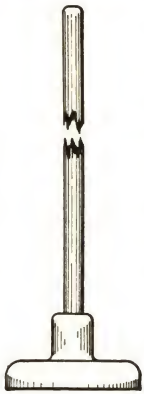


Fig. 22.
Tamping Tool

Footings. Ordinary footings for residences, barns, etc., can generally be poured their full depth starting at one corner and progressing around the entire line of footing. The concrete should be well tamped, using a tool such as shown in Fig. 22. This operation insures a good solid mass.

Sidewalks, Drives, etc. Concrete for such items can generally be poured full thickness starting at any point. The tamping tool should be used to secure a good, dense mass.

Concrete which becomes sloppy as the forms are filled, due to water being forced out of the lower layers, should be corrected by using stiffer mixtures.

Once concrete has been deposited, it remains plastic for a short time but as the reactions with the water proceed, the mix begins to *stiffen* or *set*. At this stage it is still possible to disturb the material and even remix without harming the concrete. As the reactions between the cement and water continue, the mass completely loses plasticity and cannot be remixed or even disturbed without seriously

impairing its ultimate strength. Once the mass has hardened, the chemical action continues, building up a firm internal structure which increases in strength and hardness as the action proceeds. If the concrete is kept moist, the hardening proceeds at a more rapid rate. And, if concrete is kept moist over a period of years, it gradually increases in strength.

Under Water. As previously mentioned, concrete will set or harden under water as well as in air. In depositing concrete under water, some means must be taken to prevent separation of the ingredients while passing through the water. The three principal methods are by means of closed buckets, by means of cloth or paper bags, and by means of tubes.

BUCKETS. The buckets used for this purpose have closed tops and hinged bottoms. They are lowered to the proper place and then, by means of a rope, the bottom is opened and the concrete is allowed to pour out. This method of depositing concrete is not entirely satisfactory for it is difficult to place the layers uniformly and prevent the formation of mounds.

BAGS. This method of depositing concrete under water is by means of open-woven bags or paper bags, two-thirds filled. The bags are sunk in the water and placed in courses, using the header and stretcher system if possible.

TUBES. The tubes for this purpose are from 4″ to 14″ in diameter. They extend from the surface of the water to the place where the concrete is to be deposited. Generally a cap is put on the lower end of the tube. The tube is then filled with concrete and the cap removed. As fast as the concrete flows from the bottom, more is put in at the top, creating a continuous flow.

FINISHING CONCRETE

Troweling or Finishing. The proper time for final troweling or finishing concrete is important. If the concrete is allowed to stand until it is quite stiff but still workable, the steel trowel will compact the concrete or topping to produce a dense surface without drawing the cement and fine ingredients to the surface. Too much steel troweling causes hair cracking and makes the surface so hard and fine that it turns dusty.

For gritty, nonslippery, concrete surfaces, the finishing can be done entirely by the use of the wood trowel or float. If surface water accumulates during troweling operations, it should be carefully removed with a broom or allowed to evaporate before continuing with the troweling. It is never good practice to sprinkle cement on concrete to take up surface water, for such a fine ingredient forms a layer on the surface that is likely to dust or hair-check when hardening takes place.

Floors, driveways, steps, etc. must all be finished smooth and true as far as their general surfaces are concerned. For this purpose, trowels, such as illustrated in Fig. 23, are used. Sometimes a wood trowel or float is used to approximately smooth the surfaces. A steel trowel is used to complete the smoothing of such surfaces. Fig. 24 shows the finishing of a floor.

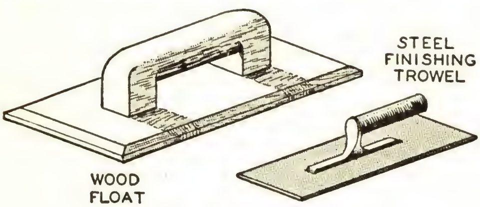


Fig. 23. Finishing Trowels

Driveways, pavements, and similar work can be finished using a belt made of wood, canvas, or rubber not less than 6″ nor more than 12″ wide and at least 2′ longer than the width of the work being finished. This is laid on the surface of the concrete *after* a wood trowel or float has been used.

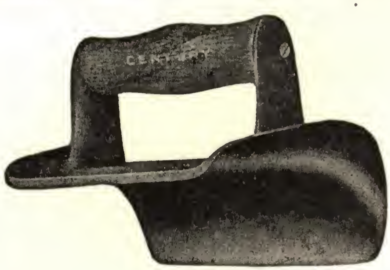
For the first application, vigorous strokes crosswise of the work and at least 12″ long should be used, advancing slowly forward along the work as the surface is made smooth and even. The second application of the belt should be made immediately after the water sheen disappears, with the strokes of the belt being not more than 4″, and the movements along the work slightly faster than for the first belting.

Curbs, such as border driveways or pavements, often have curved sections which must be finished smooth and true. The typical finishing tools shown in Fig. 25 are for that purpose.

When sidewalks, driveways, etc., are laid, they are divided into squares, rectangles, or blocks and generally have their edges slightly rounded. The joints and edges of these sidewalks and driveways are made by using the jointers shown in Fig. 26. These tools not only make the joints but smooth the topping mortar at the same time.

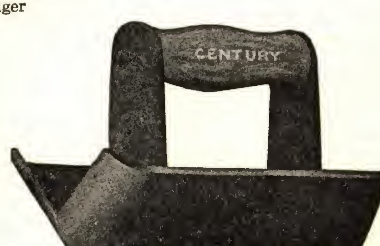
Curing Concrete. As previously mentioned, under favorable con-

Fig. 24. Finishing a Floor by the Use of a Wood Trowel or Float and a Steel Trowel
Courtesy of Lone Star Cement Company, New York



Curb Edger

Radius Tool



Inside Angle Tool

Fig. 25. Typical Finishing Tools

ditions the strength of concrete as well as its qualities of watertightness actually increase with age. The increase in strength is very fast soon after the concrete is placed and continues slowly for an indefinite period.

Concrete will harden much more quickly at 70° than, say, at 35°. The higher temperatures are thus much more satisfactory for con-

Fig. 26. Jointers

creting operations. If concreting is done during cold weather, some means should be provided to allow it to *cure* or harden at higher temperatures.

Properly curing concrete adds a great deal to its watertightness, increases its resistance to wear, and tends to give concrete a harder and denser surface than would otherwise be possible. Proper curing also prevents surface checking and dusting.

Curing can readily be done using wet burlap, canvas, and sand or straw coverings. The covering should be placed as soon as it can be done without marring the concrete surfaces. Care must be taken to keep the covering continuously wet by sprinkling for several days—the more days the better. When a covering is not used, wetting of the surface should begin as soon as possible after finishing and the surface should not be allowed to dry for several days.

Floors, sidewalks, pavements, and other flat surfaces require careful attention as moisture is lost very rapidly by evaporation due to the large exposed surfaces.

Ponding is another good method of curing flat concrete surfaces. The surface to be cured is surrounded by earth dikes and then kept flooded with water for several days.

Walls, beams, columns, etc., which cannot be protected as just explained should have the forms left in place for several days. Or, if

the forms must be removed, wet canvas can be hung over such structural members and kept wet.

The least curing period should not be less than 7 days. Longer periods, when it is practical to do so, are much more beneficial.

COLD WEATHER CONCRETING

Contrary to past opinions, good concrete can be made during cold weather as well as in warm weather if the proper precautions are taken to make sure of proper curing.

In early winter when freezing temperatures occur only during the nights, it is necessary only to protect the poured concrete. When day and night temperatures are both below freezing, the mixing water and aggregates are heated prior to mixing.

If concrete freezes after placing, the water crystallizes and thus is not available to react with the cement as required. If newly placed concrete should become frozen, it should be thawed out slowly, then kept warm for several days until it has set or become hard.

For cold weather concreting, the following procedure is recommended.

Heating Water. Water should be heated by whatever means are available. Large kettles, oil drums, etc., can be used. The temperature of the water, when it comes in contact with the cement, should not exceed 150° F. Boiling water would cause the cement to set much too quickly. If the water is boiling, it should first be added to the aggregate. This will cool it down.

Heating Aggregate. The sand and coarse aggregate should be heated separately. The heating can be done by any one of several methods. For example, the sand or coarse aggregate could be banked over a metal barrel laid on its side and with its ends removed, or over a section of large smokestack or metal drain pipe. A fire can be kept burning on the inside of the barrel, section of smokestack or pipe. The temperature of aggregates, when placed in the mixer, should not exceed 140° F.

Mixing and Placing Concrete. Cold weather concrete should be mixed as stiff as possible and yet so as to obtain a mix that can be readily placed and finished. Each batch should be placed at once to avoid loss of heat. All frost, snow, or ice should be removed from the

forms before placing the concrete. The ground upon which concrete is to be poured should not be frozen. If frozen, it should be thawed out by building fires over it.

Just as soon as the concrete is placed, it must be protected in order that it will retain its heat for at least 5 days. All flat concrete surfaces can be protected by covering them first with heavy paper and then with hay or straw to a depth of 12 or more inches. Walls, beams, and columns can be protected by coverings of hay or straw or by building canvas enclosures around them and heating the enclosures with oil stoves or coke salamanders. Keeping concrete moist is especially important while heat is being applied, since winter air when heated is very dry and takes up moisture from the concrete.

FIRE PROTECTIVE QUALITIES OF CONCRETE

The theory of the fireproofing qualities of Portland cement concrete is that the capacity of the concrete to resist fire and prevent its transference to steel is due to its combined water content and porosity. In hardening, concrete takes up about 18 per cent of the water contained in the cement. This water is chemically combined and not given off at the boiling point. On heating, a part of the water is given off at 500° F., but the dehydration does not take place until 900° F. is reached. The mass is kept for a long time at comparatively low temperature by the vaporization of water absorbing heat. A steel beam embedded in concrete is thus cooled by the volatilization of water in the surrounding concrete. Resistance to the passage of heat is offered by the porosity of concrete. Air is a poor conductor and an air space is an efficient protection against conduction. The outside of the concrete may reach a high temperature but the heat only slowly and imperfectly penetrates the mass and reaches the steel so gradually that it is carried off by the metal as fast as it is supplied.

Cinder concrete, for example, being highly porous, is better for fireproofing than a dense concrete made using crushed stone or gravel as coarse aggregate.

Thickness of Concrete Required for Fireproofing. Actual fires and tests have shown that 2″ of concrete will protect an **I** beam with good assurance of safety. Reinforced concrete beams and girders should have a clear thickness of 1½″ of concrete outside the steel on the sides

and 2″ on the bottom. Structural steel columns should have at least 2″ of concrete outside of the farthest projecting edge.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. What the most important item from the standpoint of proportioning is in the making of concrete?

Answer. The amount of water used per sack of cement.

2. What happens to a concrete mix when too much water is used per sack of cement?

Answer. The cement paste becomes diluted to the extent that it does not properly bind the coarse and fine aggregates together.

3. If bank-run sand and gravel can be used as aggregate without regrading? Why?

Answer. Bank-run materials generally contain too high a percentage of sand to permit their being used as an aggregate without regrading.

4. Whether concrete cures best in moist or dry surroundings?

Answer. In moist surroundings.

5. What governs the strength of any concrete beyond the quality of aggregates?

Answer. The cement paste.

6. What the two principal requirements of hardened concrete are?

Answer. Strength and durability.

7. What is meant by the term segregation in terms of concrete?

Answer. Segregation is the separation of the coarse from the fine aggregates.

8. What conditions are necessary for the proper hardening of cement paste?

Answer. Time, the presence of moisture, and favorable temperatures.

9. If any heat is generated by concrete?

Answer. The chemical action, which takes place as concrete hardens, generates heat.

10. Which concrete mix has more water added to it—one to make a water tank or one to make a footing?

Answer. The mix used to make a footing.

11. How the tensile strength of concrete beams is increased?

Answer. By putting steel reinforcing rods in the concrete at the time it is poured.

12. What type of sandstone is suitable for coarse aggregate?

Answer. Only the hard varieties.

13. What geological type of sand is generally best?

Answer. Quartz.

14. What the colorimetric test is used for in concrete work?

Answer. As a means of determining the presence of harmful vegetable matter in bank, or even river bottom, sand.

15. How much water a cubic foot of wet sand contains?

Answer. About ½ gallon.

16. If it is permissible to add more water when a concrete mix is too stiff?

Answer. Under no circumstances should more water be added to a mix than the regular proportions call for.

REVIEW QUESTIONS

1. What is meant by grading in terms of aggregate?
2. Why should coarse aggregates be well graded?
3. Why should fine aggregates be well graded?
4. What is the difference between crushed stone and gravel?
5. What is meant by curing in terms of concrete?
6. Why must proper curing of concrete be carefully provided for?
7. Explain the procedure to follow in making economical mixes of concrete.
8. What tests should always be made relative to bank gravel before it is used in concrete?
9. Why must newly placed concrete be carefully spaded?
10. What type of a mix is most apt to segregate—a wet or a stiff mix?
11. What type of a mix—wet or stiff—should be used for reinforced concreting when the reinforcing rods are close together?
12. If cement forms into lumps before being used, how can it be tested to see if it is satisfactory for use?
13. Explain how to judge the allowable size for coarse aggregate in a mix.
14. Are round particles of sand as desirable as so-called sharp sand?
15. Why is it poor practice to sprinkle cement on the surface of concrete during the finishing operations?
16. What happens when the surface of a concrete mix is steel-troweled too much?
17. What happens in concrete made by the use of dirty aggregates?

CHAPTER IV

Blueprint Reading

QUESTIONS CHAPTER IV WILL ANSWER FOR YOU

1. *What is the purpose of the section view?*
2. *What are the most commonly used small scales and what is the reason for their use?*
3. *How does a mason or carpenter locate a door or window when exact dimensions for the location are not given?*
4. *What are conventions and how are they used in working drawings?*
5. *What are symbols and how are they used in working drawings?*

INTRODUCTION TO CHAPTER IV

If you make a trip by automobile, even over a short distance, you probably will use a road map. The farther from home you go, the greater the importance of the map becomes in helping you find your way about the strange countryside. Maps are used at sea and by pilots flying cross-country hops. Crude maps, drawn from second and third-hand information, were used by the early settlers as they moved westward across the nation. When the universal importance of the map is considered, its great necessity readily becomes apparent. It provides a logical plan for action. Without it, costly mistakes in time and money would be made and movement from one place to another would be virtually impossible.

There are guides in the building trades, in all industry in fact, comparable to the road map of the traveler. These guides are plans. When used in the building trades, they are usually blueprints. Without them it would be impossible to construct anything but the most rudimentary structure. The importance of blueprints and the full understanding of them by the mason cannot be overemphasized.

A careful study of this chapter will prepare you for your everyday use of working drawings which you will be certain to find on every job. You will learn first the three principal forms called views, in which working drawings appear. You will be told the purpose of each form of presentation. You will discover each view calls for a different manner of representation of the structural material involved as well as of the various structural items such as windows, doors, chimneys, etc. You will learn the importance of scaling and dimensions. You will be taught the use of conventions.

When you have completed the reading of this chapter, you will have a sound understanding of all the basic ideas behind working drawings. You will have had adequate preparation for understanding the complicated working drawings you will find in the field.

PURPOSES OF WORKING DRAWINGS

Perhaps you already know or can guess why working drawings are required and what their purpose is. It may be that you never have had any previous occasion to concern yourself about them. In either case, a short review covering the purpose of working drawings and the information they give will serve to make certain that you approach the study of how to read them with the correct viewpoint.

When an architect or other designer has discussed a proposed house with the owner, he has a rather complete mental picture of the house and in his own mind knows pretty well how it should look, how many rooms it is to have, what materials will be used, the sizes of its various parts, and many other details concerning it.

However, a mental picture at best cannot be absolutely complete or accurate because there are too many items—good exterior design, locations of windows and doors, sizes of supporting or structural members, etc.—which have to be drawn before they can be developed properly.

Even if a complete and accurate mental picture of a proposed house could be developed in the designer's mind, he would find it impossible to explain his ideas to the masons and other builders merely by talking to them. Therefore, you can understand easily that there are two important reasons among many others why working drawings are required and what their purpose is.

First, designers must make actual drawings for a proposed building so that they can design it properly, show the arrangement of rooms, indicate materials, give required material sizes, etc., all of which in turn makes for complete and accurate planning.

Second, designers must have copies (working drawings) of these drawings to show masons and other builders in order to explain to them how the building is to look, how many rooms it must have and their arrangement, what materials must be used, what sizes are necessary, and almost countless other details.

The foregoing explanations might be summed up by saying that from your standpoint as a mason, the purpose of working drawings is to show every detail of a proposed building so that all the information needed by masons and the other builders is perfectly clear.

The drawings which designers make and from which working drawings (sometimes called blueprints) are made, while being pictorial in many respects and thus easy to visualize, are also composed of many special representations which are used to indicate much of the information required. These representations are commonly known as elevation views, plan views, section views, symbols, and conventions and are in reality a special architectural alphabet or language by which materials, sizes, walls, windows, and other parts of a building may be indicated.

The purpose of this chapter is to present explanations and illustrations of typical working drawings in such a manner that you will learn to visualize and understand them both from the standpoints of actual masonry practice and as an aid to your study of this book.

ELEVATION VIEWS

The elevation views of an object (or a building) are a series of picture-like drawings which show what the various sides of the object look like when viewed from a point directly in front of each side.

To understand this definition better, study (A) and (B) of Fig. 1.

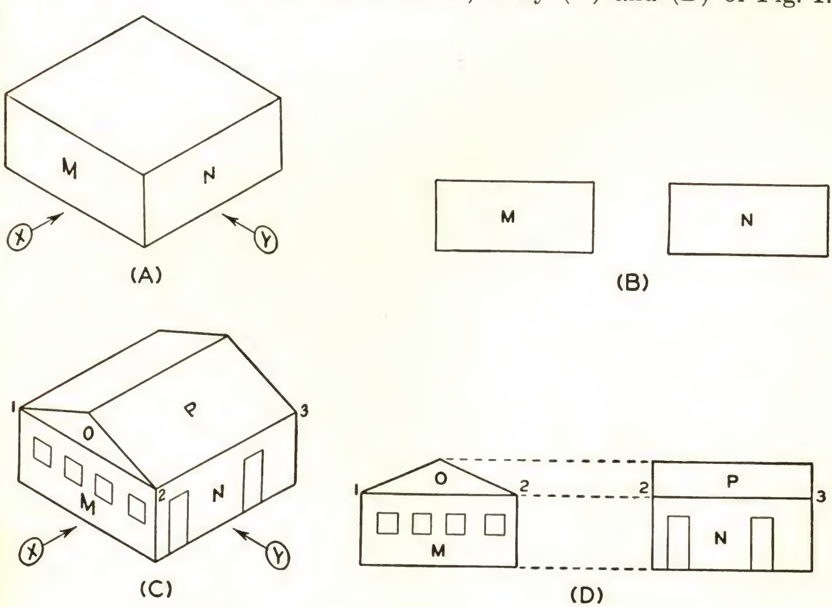


Fig. 1. How to Visualize the Elevation View

In (A) is shown an ordinary wooden block which has four sides. If you imagine that you are standing directly in front of the side marked *M* and that you are looking straight at the block from point *X*, the view you would see is as shown at the left in (B). If you imagine you are standing directly in front of the side marked *N* and that you are looking straight at the block from point *Y*, the view you would see is as shown at the right in (B).

View (B) in Fig. 1 is called the *elevation view* of the block shown at (A).

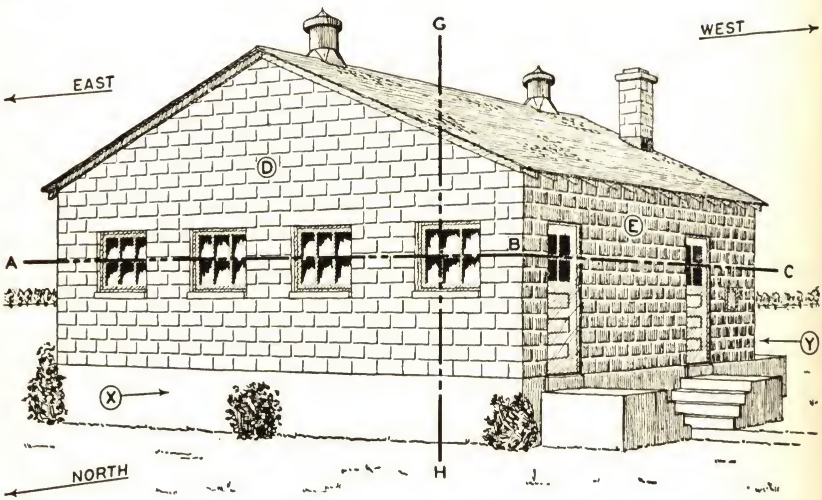


Fig. 2. General or Pictorial View of a Milkhouse

Now suppose we add what looks like a roof, windows, and a door to the block, making it look something like a house as shown in (C) of Fig. 1. Then repeat the process of imagining that you are looking at it from points *X* and *Y*. If you imagine you are standing directly in front of the side marked *M* and that you are looking straight at the house from point *X*, the view you would see is shown at the left in (D). If you view the side marked *N* from point *Y*, the view you would see is as shown at the right in (D).

If you imagine that (C) is a house or a farm building, then the lines 1, 2 and 2, 3 represent the place where the roof and side walls meet. These lines also are shown in (D).

Fig. 2 is a general or pictorial view of a typical milkhouse which is seen frequently on dairy farms. Suppose you were standing at point *X* looking directly at the side marked *D*. The view you would see is that shown in (A) of Fig. 3. In like manner, if you were standing at point *Y* looking directly at the side marked *E*, you would see the view shown in (B) of Fig. 3.

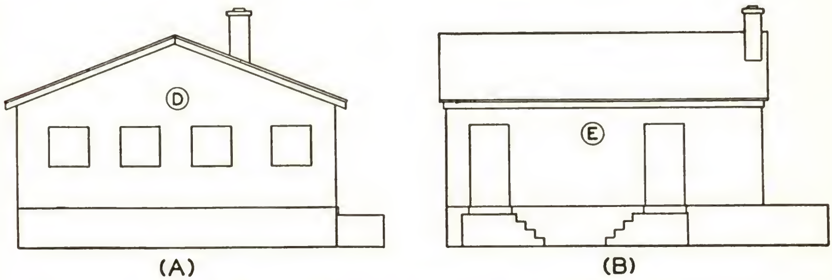


Fig. 3. Elevation Views of Milkhouse Shown in Fig. 2

At the beginning of this explanation of elevation views, the definition stated that elevations are picture-like drawings which show what the various sides of a building look like when viewed from a point directly in front of each side. By studying Figs. 2 and 3, you can see why elevations are called picture-like drawings. They show, as an actual picture would, what the various sides of the house are like. They show the windows, doors, and chimneys; heights, widths, and the spacings or locations of windows and doors. A little later you will learn more important things which elevation views show.

The various elevation views of a plan are named for the purpose of identification when referring to them and are called south, north, east, and west elevations.

Elevation View Symbols. In order to show various materials such as brick, concrete block, stucco, etc., the designer uses what are called symbols. In other words, if an outside wall is to be made of concrete block, the designer uses a standard symbol which all people in the building trades recognize as representing concrete block. Items such as windows, doors, chimneys, ventilators, etc., all of which are large enough to be recognized easily on small scale drawings, are drawn exactly as they would appear if viewed from a point directly in front of them.

The most commonly used symbols are illustrated in Fig. 4 and briefly explained in the following:

Walls. The symbols (A) through (L) in Fig. 4 are used to indicate various materials used in walls. Thus, if a building is to be constructed so that it has concrete block walls, the symbol shown in (B) would be used.

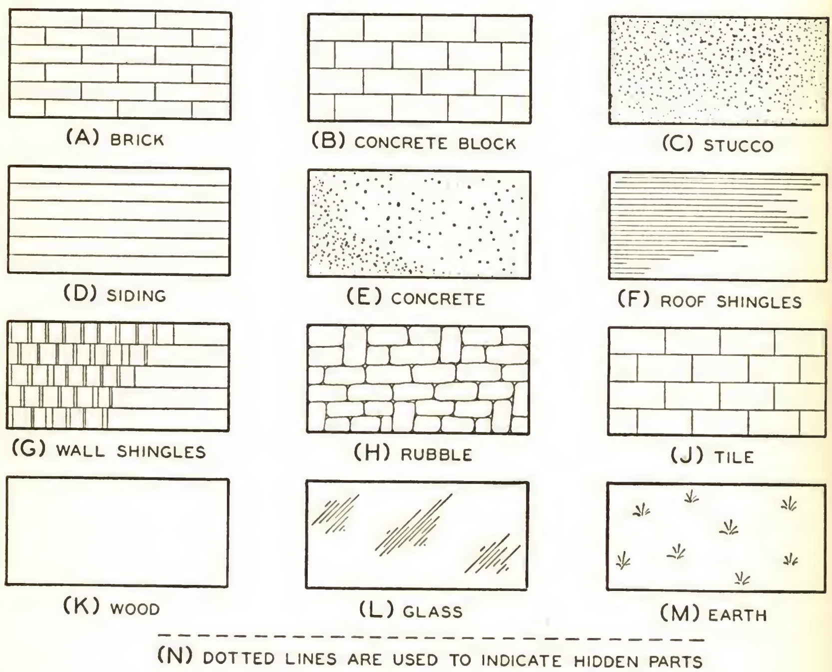


Fig. 4. Elevation View Symbols

Roofs. The symbol shown in (F) of Fig. 4 is used to represent shingle roofs. If rolled roofing is to be used, no symbol is required other than a printed note to specify the type or kind.

Doors, Windows, and Ventilators. The symbols for these items are drawn exactly as they appear, using the glass symbol where necessary.

Chimneys. Chimneys also are drawn exactly as they appear except that the proper symbol, such as concrete block, is used to indicate material.

Earth. When elevation views of earth are required, they are drawn as shown in (M) of Fig. 4.

Dotted Lines. The dotted line is used to indicate invisible lines as is explained a little later.

Miscellaneous. Other symbols as for downspouts, dormers, and coal doors are drawn exactly as they appear.

Scaling and Dimensions. Designers, in preparing working drawings, employ a system whereby their drawings are made to what is called a *small scale.* In other words, instead of making working drawings full size, they draw them, for example, to 1/48 of their actual size. This practice is necessary in order that full views can be shown on comparatively small sheets of paper. This process is known as drawing to scale.

Suppose a designer wanted to draw a line whose actual length was 25′ on a piece of paper about twice the size of the pages of this book. It is evident that he could not draw the line anywhere near its actual length. Therefore he must represent it by substituting some smaller unit of measure for each foot of length. The most commonly used smaller unit of measure is a quarter inch. By this process, he could draw the line 25 quarter inches long and indicate that each 1/4″ represents one foot. The line he draws will actually measure 6 1/4 inches. Working drawings made in this manner would have printed on them the specification 1/4″ = 1′ 0 inches. The most commonly used small scales are the 1/4″ = 1′ 0″, the 3/8″ = 1′ 0″, the 1/8″ = 1′ 0″, the 1/2″ = 1′ 0″, and the 3/4″ = 1′ 0 inches.

Frequently, lines which are actually less than 1′ long must be drawn to a small scale. For example, take a line whose length is actually 6 inches. To draw this line to the 1/4″ = 1′ 0″ small scale, we would make it one half of 1/4″ or 1/8″ long. Or, if a line was actually 3″ long, we would draw it one fourth of 1/4″ or 1/16″ long. Thus a line having an actual length of 25′ 6″ would, in the 1/4″ = 1′ 0″ small scale, be drawn 25 quarter inches plus one half of one 1/4″ long. This would be 6 1/4″ plus 1/8″ or 6 3/8″ long. The same general proportions are true for other small scales.

As a designer draws working drawings, he indicates lengths, widths, thicknesses, etc., of practically all parts of a building being shown in the working drawings. Thus, if a designer shows a dimension of 25′ 6″

along a wall, the mason doing the construction work for the building knows that wall is to be 25′ 6″ long. In like manner the mason *reads* the working drawings to learn all the other necessary information pertaining to lengths, widths, and thicknesses.

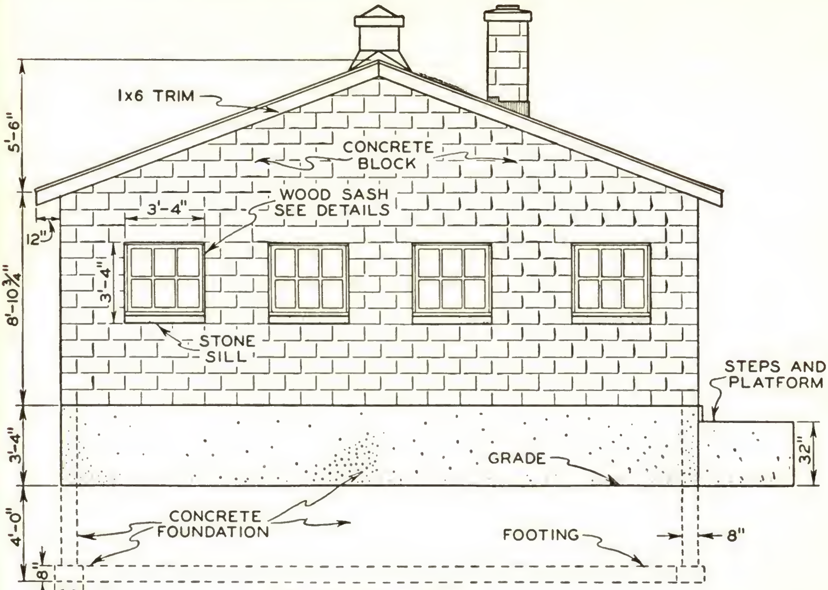
Sometimes, for any one of several reasons, designers do not show dimensions indicating the exact location of a door or of an interior partition. In such cases the mason, or other builder, can *scale* the working drawing to find the necessary dimension. Scaling is a simple operation which can be done using a common folding rule or 12″ rule. If the working drawings were made to the $\frac{1}{4}$″ = 1′ 0″ small scale, the operation consists of putting the rule on the working drawing so as to determine the number of quarter inches there are between the points or the length being scaled. If it turns out that 10 whole quarter inches plus $\frac{1}{4}$ of another quarter inch are involved, it is evident that the dimension desired is 10′ 3 inches.

Drawing Symbols to Scale. Every symbol used on an elevation view is drawn to scale as nearly as possible. For example, the symbol for concrete blocks is drawn so that the various rectangles are to scale. Thus, a 15″ long concrete block, according to the $\frac{1}{4}$″ = 1′ 0″ small scale, is drawn $\frac{5}{16}$″ long. In like manner, windows, doors, chimneys, and steps are all drawn to scale. Unless the symbols as well as the main outline of a building are drawn to scale, the elevation views will not be in correct proportion and thus will be useless.

A few exceptions to the foregoing rules are siding, rubble, and other such items which are irregular in shape or too small to be drawn conveniently to scale. In such cases, their symbols are drawn approximately to scale.

Elevation View Working Drawings. Fig. 5 shows the same elevations as shown in Fig. 3 except that the symbols and dimensions have been added to make them regular working drawings which indicate the following information:

The walls are to be made of concrete blocks. This information is indicated by various patches of the concrete block symbol which is shown in (B) of Fig. 4. The chimney is also to be made of concrete blocks and is to have flue lining and a cement cap. The 33″ dimension in the west elevation shows that the top of the chimney is to be that distance above the roof vertex. There are to be 4 windows in the north



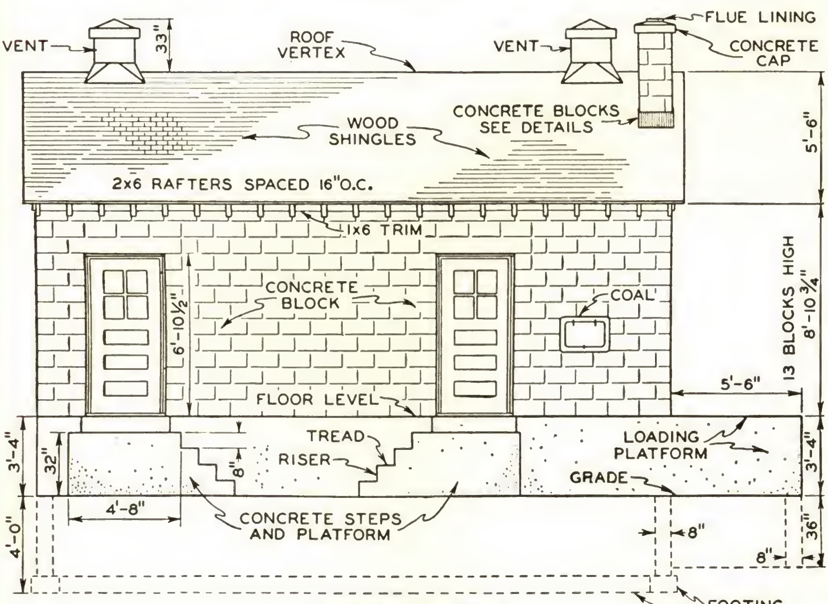


Fig. 5. End and Front Elevation View Working Drawings for Milkhouse

elevation each of which is to have 6 lights and a wood sash. The note (see details) indicates that further information is shown in detail drawings. These drawings are explained later in this chapter. The windows are to be 3′ 4″ square in over-all size. Each window is to have a stone sill.

The west elevation shows that two doors are required, each of which must be 6′ 10½″ high. Each door is to have 4 lights in the top half. The floor level is shown to be 3′ 4″ above the ground level or grade. The dotted lines show that the foundation and footings extend below the ground level and the dimension shows that the depth is 4 feet. Dotted lines are used to indicate the foundation and footing below the ground because of their being invisible. The various dimensions specify that the foundation is to be 8″ thick and that the footings are 8″ deep and 14″ wide. Concrete is specified for both foundations and footings. Both the north and west elevations show that two concrete platforms and steps for them are required near each of the doors on the west elevation. The platforms each have steps consisting of three treads and four risers. The platforms are 32″ above grade, are 5′ 6″ wide, and have 8″ foundations which extend 36″ below grade. No footings are indicated for the platform foundations.

The ceiling height for this one story building is shown as 8′ 10¾ inches. The vertex of the roof is to be 5′ 6″ above the ceiling. The roofing is to be wood shingles and the rafters are to be 2 x 6 spaced 16″ on centers (O.C.). Two roof ventilators are required.

The foregoing constitutes typical examples of the information indicated in elevation views. With such information, you can form an accurate picture of the designer's idea of the building.

PLAN VIEWS

Thus far in your study of working drawings you have learned what elevation views are and that they indicate a great deal of information about the *exteriors* of buildings. But, as you have probably noticed, they contain very little information pertaining to the *interiors*. Therefore, additional different kinds of drawings must be employed to indicate the information necessary for the interiors. Such drawings are called *plan views*.

In learning to visualize elevation views, you imagined that you

were standing in front of and looking directly at the various sides of a building. In learning to visualize plan views, you must imagine that you can saw the top part of a building off, remove that top portion, and look directly down on the cut surface of the lower part. This can be much better understood by studying (A), (B), and (C) of Fig. 6.

(A) of Fig. 6 shows a box having four sides, a top, and bottom all made of wood about 1″ thick. Imagine that the box is sawed into two

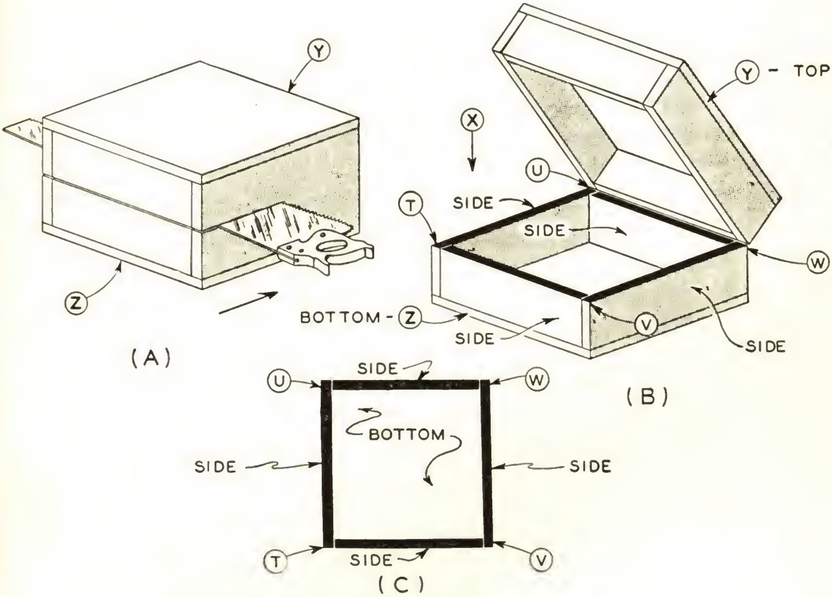


Fig. 6. How to Visualize a Plan View

halves, *Y* and *Z*, as indicated. Then, as shown in (B) of Fig. 6, further imagine that the top half, *Y*, can be moved up and back as though there were a hinge at *UW*. Finally, imagine you are looking straight down on the lower half, *Z*, from point *X* directly above it. You would see the cut surfaces, as shown in black, of sides *UT*, *TV*, *VW*, and *WU* and also the bottom of the box. If the box were moved to the position shown in (C) of Fig. 6, the view you would see constitutes the plan view of the box.

The interiors of buildings such as the milkhouse shown in Fig. 2 are divided generally into various rooms instead of being one large

area as shown in (C) of Fig. 6. If the milkhouse were sawed in half, the various rooms and all partitions and walls would be visible the same as the sides of the box are visible in (C) of Fig. 6.

Note the line *ABC* in Fig. 2. Imagine that the milkhouse could be sawed in half at the level of this line and that the top half could be moved up and back as shown in (A) of Fig. 7, just as though there were a hinge along the side *EF*. Finally, imagine that you are looking straight down on the lower half from point *X* directly above it. You would see the cut surfaces, shown in black, of all walls and partitions and of the chimney. You would see also that the windows and doors had been cut. The line *ABC* in Fig. 2 was placed so as to include all windows and doors in the cut surfaces shown in (A) of Fig. 7. The reason for this will be apparent when you study plan view symbols.

If the milkhouse is moved into the position shown in (B) of Fig. 7, you see what constitutes a plan view of it. The designer of such buildings draws plan views as a means of accurately showing the arrangement and sizes of rooms, chimneys, walls, partitions, windows, and doors. Fig. 7 at (B) contains no symbols or dimensions but it does illustrate a plan view.

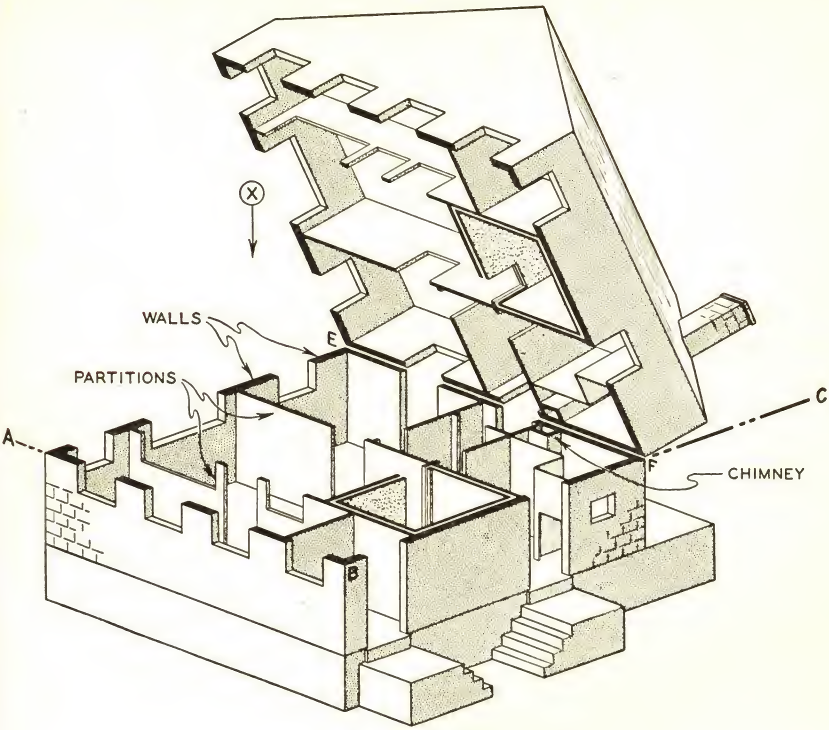
Plan View Symbols. Regular plan views do not have the walls, partitions, etc., blackened. Instead, a symbol is used to indicate the type of material they are to be constructed of, similar to that explained for elevation view symbols.

The most generally used plan view symbols are illustrated in Fig. 8 and are briefly explained as follows:

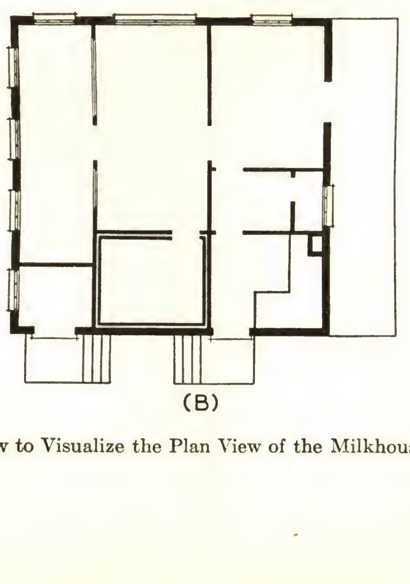
WALLS AND PARTITIONS. The symbols (A) through (M) in Fig. 8 are used to indicate various materials used in walls and partitions. Some of these symbols indicate the same materials found in the elevation view.

You will notice that walls and partitions are indicated by two parallel lines between which the proper material symbol is employed. For example, note the symbols shown in (C) of Fig. 8 and in (B) of Fig. 4. Both of these symbols indicate concrete block. The difference in the two symbols is due to their manner of presentation in the plan and elevation views.

When insulation is required in walls and partitions, either of the symbols shown in (L) or (M) is used between the parallel lines.



(A)



(B)

Fig. 7. How to Visualize the Plan View of the Milkhouse in Fig. 2

Windows. Double-hung, casement, and simpler types of windows are indicated by such symbols as shown in (N) and (P) of Fig. 8. The symbol shown in (N) for concrete block is the proper one to use on plan views of the milkhouse illustrated in Fig. 5.

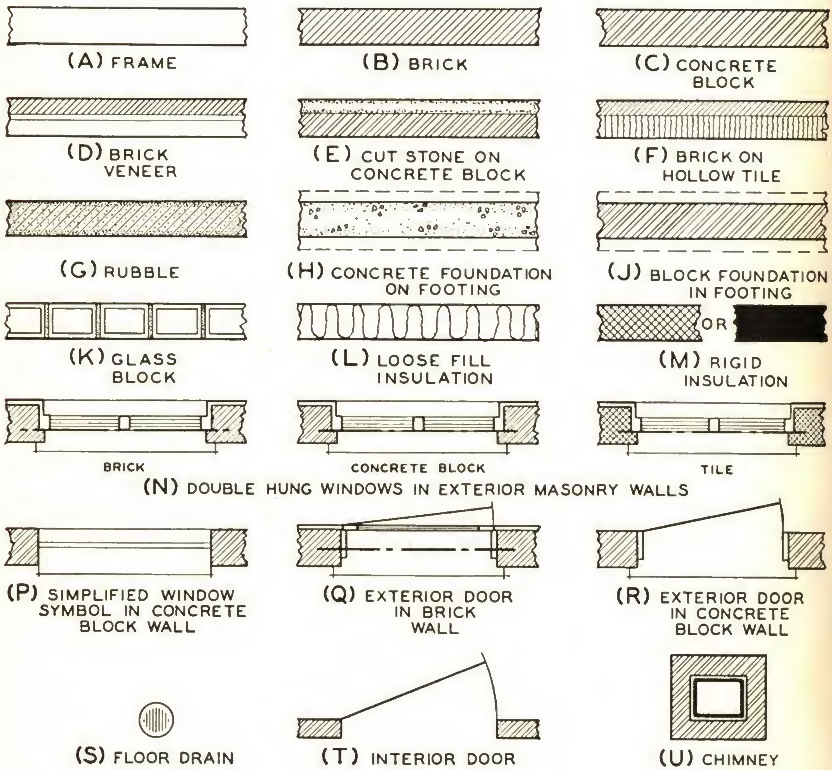


Fig. 8. Plan View Symbols

Doors. Doors are indicated in plan views by such symbols as shown in (Q), (R), and (T) of Fig. 8. The symbol shown in (R) is the proper plan view symbol for the doors in Fig. 5.

Chimneys. A typical chimney symbol is shown in (U) of Fig. 8. You will notice that this symbol shows cut surfaces the same as in Fig. 7 except that the proper material is shown.

Floor Drains. The symbol shown in (S) represents a floor drain usually used in concrete floors.

Plan View Conventions. There are numerous items generally found in houses and other buildings which must be present in the plan views but which cannot be shown by symbols as just described. Such items include stairs, sinks, and bath tubs. In order to indicate these items, pictorial representations, called conventions, are used.

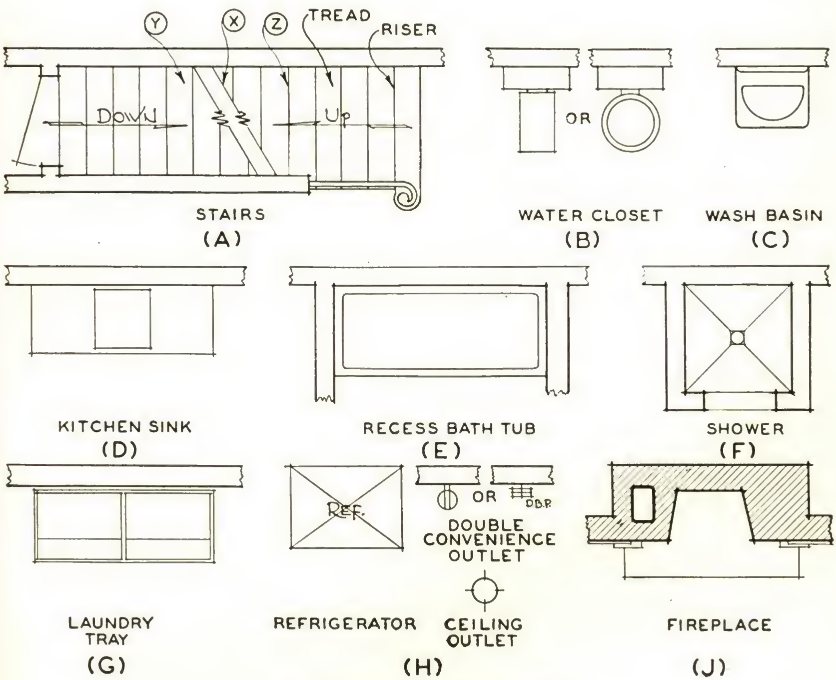


Fig. 9. Plan View Conventions

The most commonly used conventions are illustrated in Fig. 9 and are briefly explained in the following:

Stairs. The convention shown in (A) of Fig. 9 represents stairs. If a single flight is to be represented, the cutting lines at X are omitted. But when one flight is directly over another, as so often happens in two story houses, the cutting lines are drawn to indicate that part Y represents the upper flight and that part Z represents the lower flight.

Plumbing. The conventions shown from (B) through (G) represent typical plumbing fixtures.

Fireplaces. The convention shown at (J) is a typical fireplace

representation. Such conventions vary in shape and detail according to the specific fireplaces they represent but are all near enough alike to be easily recognized.

Miscellaneous. Sometimes various objects such as motors, boilers, compressors, and brine tanks must be indicated in plan views. Generally they cannot be drawn conveniently to small size. Therefore, plain rectangles, circles, or combinations of rectangles and circles are used to represent them. Such conventions are then named.

Scaling and Dimensions. The explanations given for scaling and dimensions pertinent to elevation views applies equally well to plan views.

Drawing Symbols and Conventions to Scale. The symbols for walls and partitions are drawn to scale only to the extent of making the parallel lines such distance apart as to represent accurately the thicknesses of the walls and partitions. Window and door symbols are drawn accurately to scale so far as their widths and wall and partition thicknesses are concerned.

Chimney and floor drain symbols are drawn accurately to scale so far as their exterior dimensions are concerned.

All conventions are drawn accurately to scale so far as their exterior boundaries are concerned. This is important as a means of keeping all proportions correct.

Plan View Working Drawings. Fig. 10 shows the same plan view illustration as in Fig. 7 except that the necessary symbols, conventions, and dimensions have been added to make it a regular working drawing. In other words, the designer has shown his ideas completely. By reading his working drawings, you can visualize exactly what they are.

Study Fig. 10 carefully. Check all symbols and conventions to make sure you understand what is required. Study the dimensions. Note how the windows, doors, and chimney check with the elevation working drawings in Fig. 5. Pay particular attention to the fact that the plan view shows information not given in the elevation views. As an example of this, note that the exact location and size of the chimney is given in the plan view, whereas in the elevation views its size is not given at all and its location is indicated approximately.

This plan view will be used as the basis of test questions which appear at the end of the chapter.

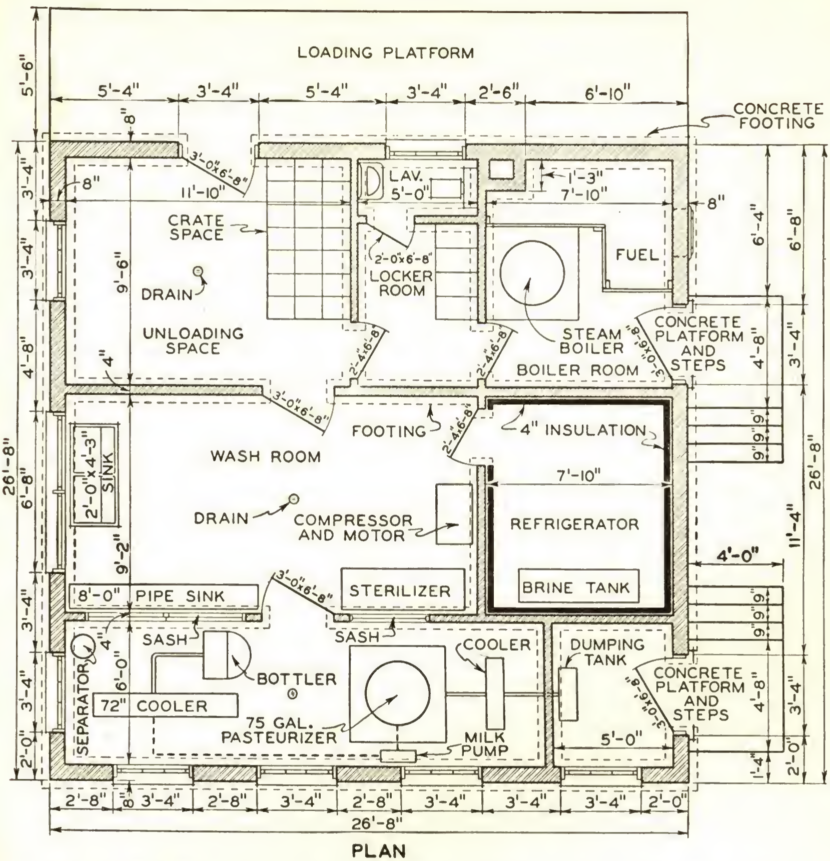
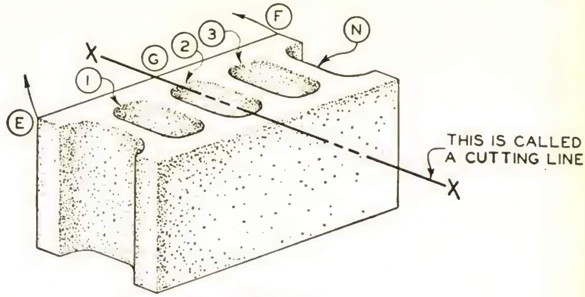


Fig. 10. Plan View Working Drawings of the Milkhouse Shown in Figs. 2 and 5

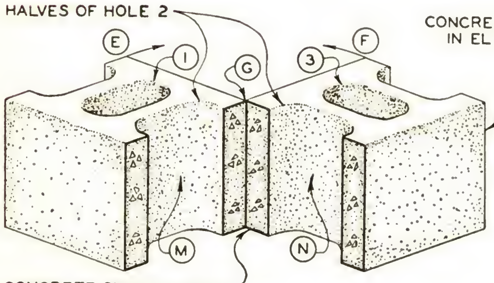
SECTION VIEWS

Up to this point in your study of working drawings you have learned how to visualize elevation and plan views. You have also learned how to read such drawings. However, there is one more important type of drawing which you must learn to understand before you can read what constitutes complete working drawings of a building. Once you have studied the following type of drawing, you will understand better the various illustrations used to amplify other chapters in your study of this book.

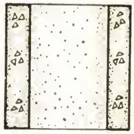
Section views of various structural parts are similar to plan views in that they represent cut surfaces. However, instead of imagining that



PICTORIAL VIEW OF A
TYPICAL CONCRETE BLOCK
(A)

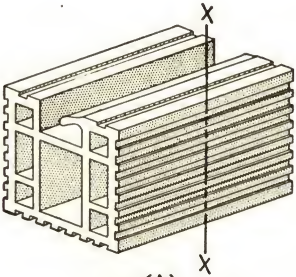


BLOCK AFTER IT HAS BEEN CUT
IN HALF IN DIRECTION OF LINE X-X
(B)

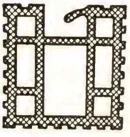


REGULAR OR STANDARD SECTION
VIEW OF A CONCRETE BLOCK
(C)

Fig. 11. How to Visualize a Section View of a Concrete Block



(A)
PICTORIAL VIEW
OF TYPICAL
HOLLOW TILE UNIT



(B)
SECTION ON LINE
X–X OF TYPICAL
HOLLOW TILE UNIT

Fig. 12. Pictorial and Section View of a Typical Hollow Tile Unit

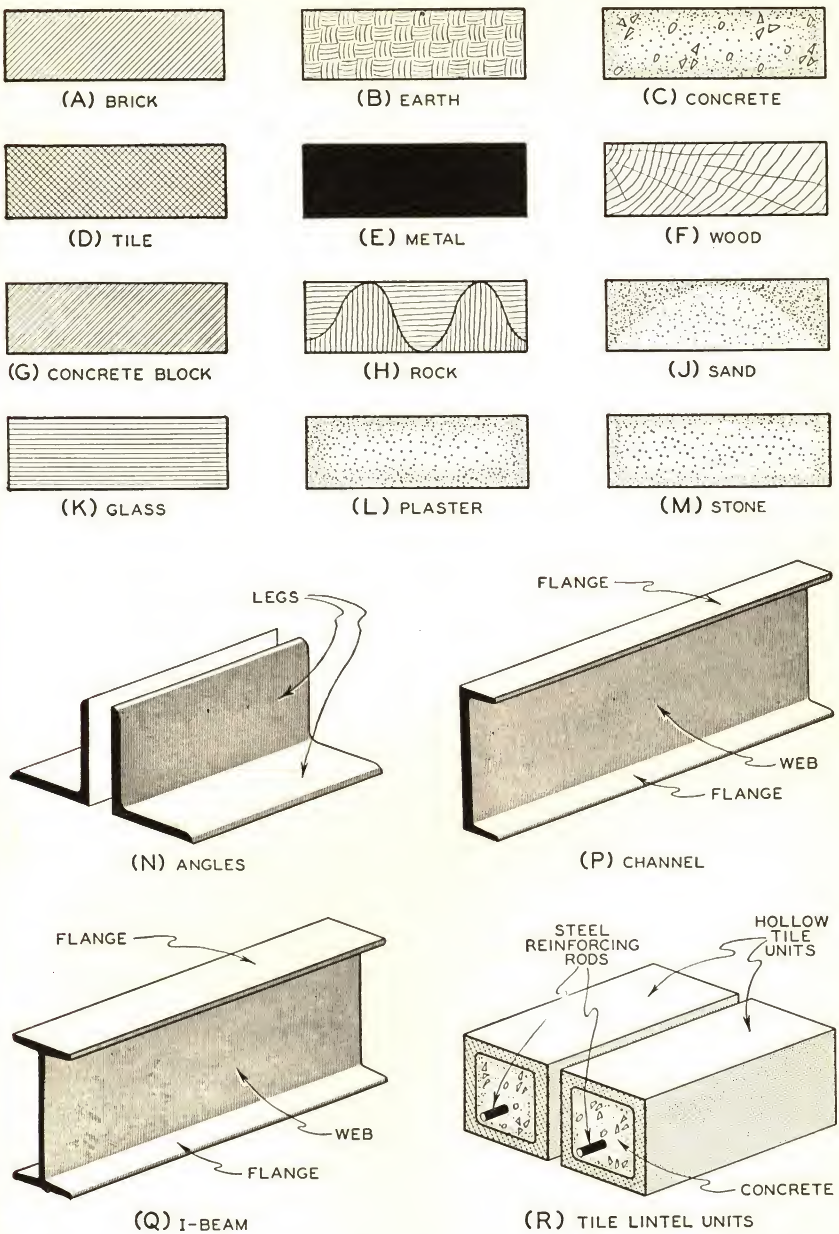


Fig. 13. Section View Symbols and Their Use in Pictorial View Presentation of Steel Beams and Tile Lintels

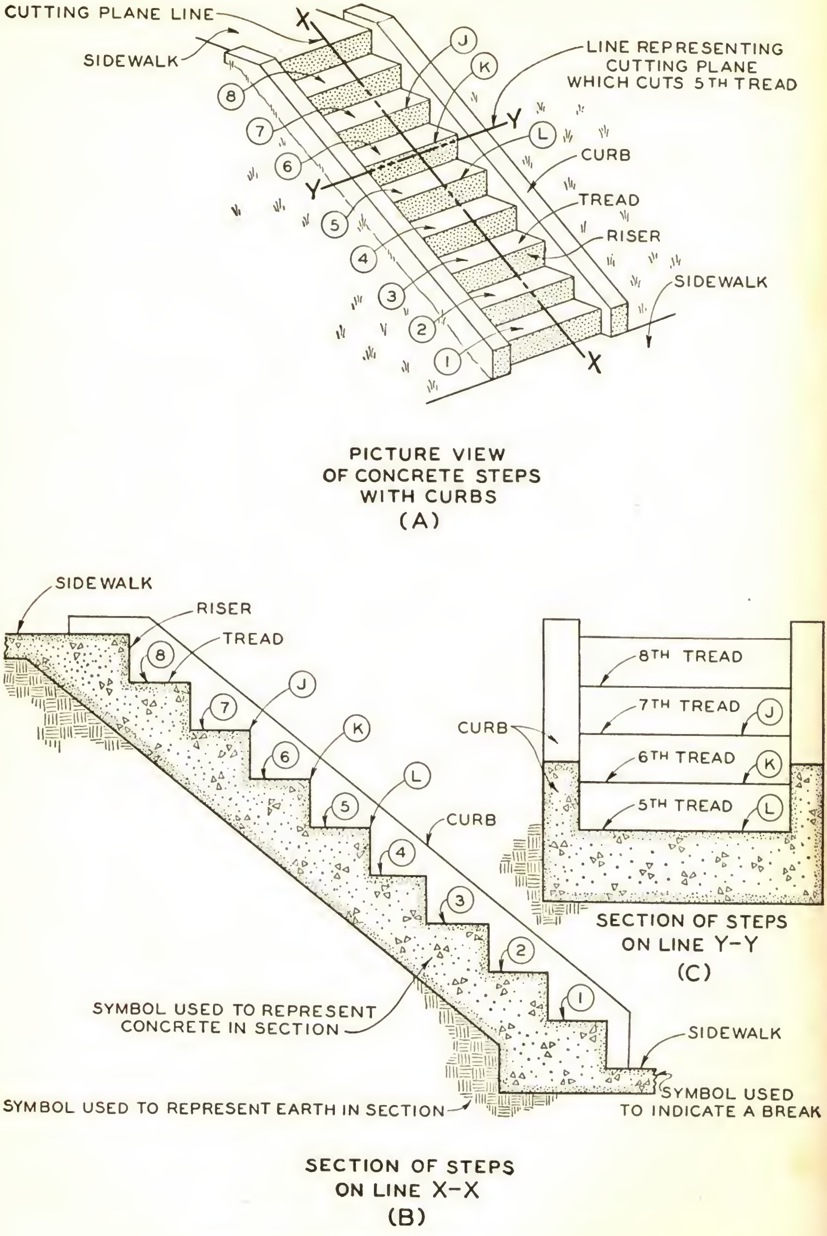


Fig. 14. Pictorial and Section Views of Concrete Steps with Curbs

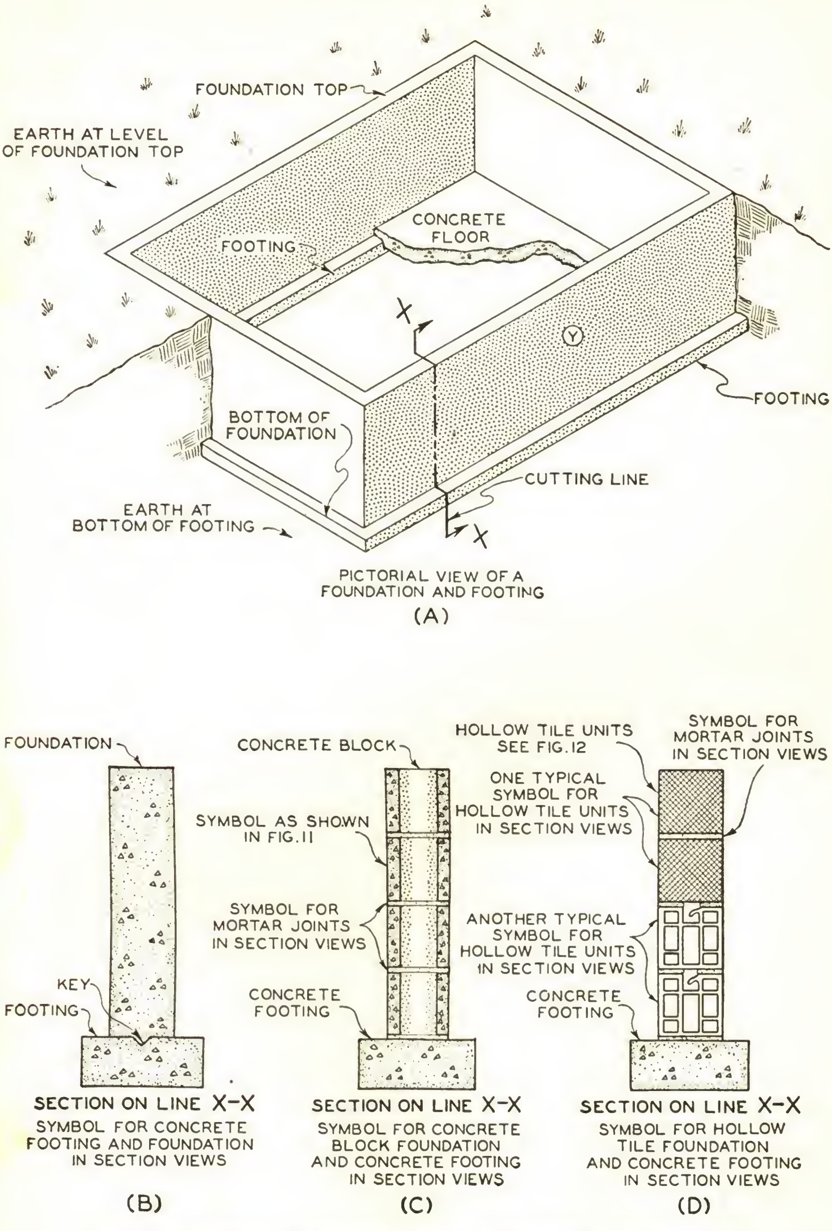


Fig. 15. Pictorial and Section Views of Footings and Foundations

section views represent horizontally cut surfaces, we imagine that they represent vertically cut surfaces.

As an example of this, we will study Fig. 11. At (A) is shown a pictorial view of an ordinary concrete block. Imagine that this block

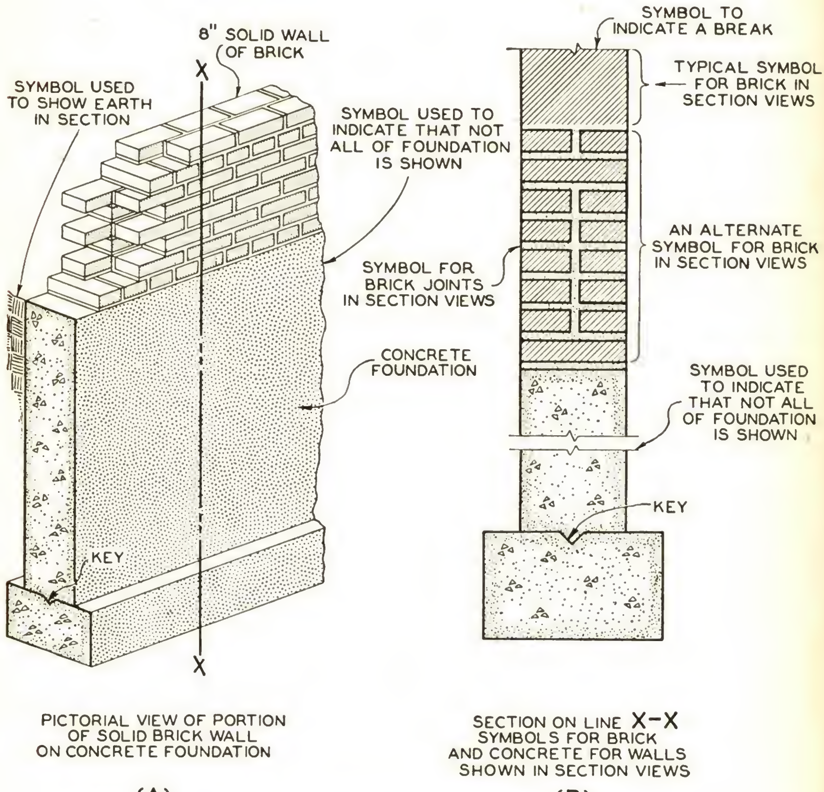


Fig. 16. Pictorial and Section View of a Solid Brick Wall

is cut in half at the line *X-X*. Then imagine that after it was cut, the halves of the block marked *E* and *F* could swing around in the direction of the arrows, using *G* as a hinge. The illustration at (B) shows the block after its two halves have been swung apart. Also note the positions of corners *E* and *F* at both (A) and (B).

The cut surfaces at *M* and *N* constitute section views of the block. Note the symbol at (C) for the exterior of the block. This is the same

as given at (E) in Fig. 4. The symbol for concrete in section, however, is a new one. The illustration shown at (C) is a regular or standard section view of a concrete block. Once you learn how to visualize this section view, you will understand what section views are.

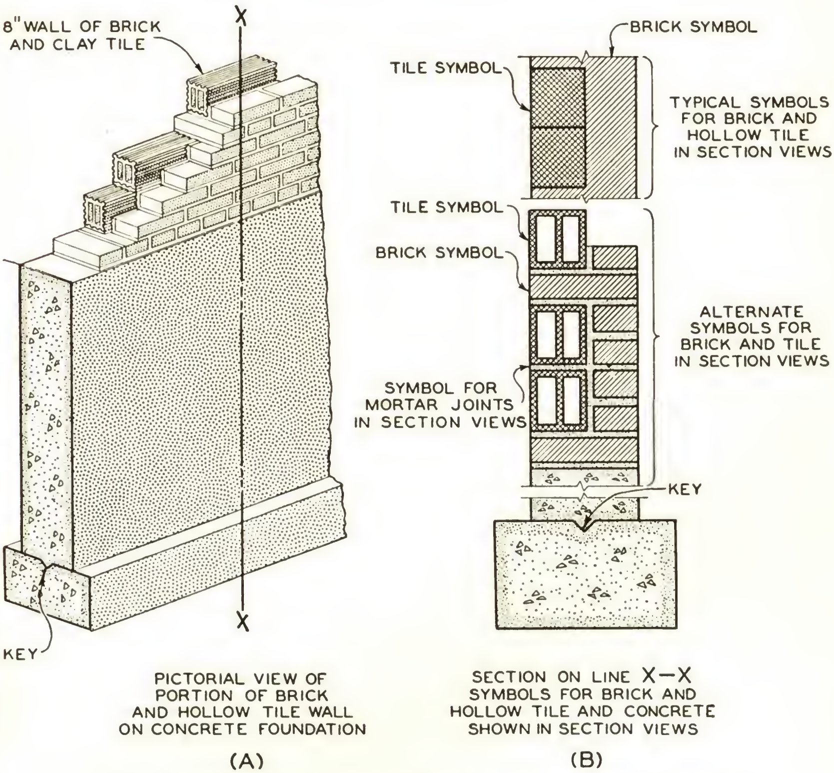


Fig. 17. Pictorial and Section View of a Brick and Hollow Tile Wall

Fig. 12 shows another typical example of the section view. At (A) is shown a perspective or picture view of an ordinary hollow tile unit. Imagine that this unit is cut in half at line X-X and the two halves swung around as explained for Fig. 11. The illustration in (B) of Fig. 12 is a section view of the tile unit.

Section View Symbols. You are already familiar enough with symbols to understand the first 12 shown in Fig. 13. The symbols shown in (N), (P), and (Q) are those for the three most used steel shapes. The black ends are the section view symbols. The symbol shown in

(R) is for a reinforced tile lintel, examples of which you will see often where tile walls are being laid.

The explanations given for scaling, dimensions, and the drawing to scale of symbols for elevation and plan views apply equally well to symbols for section views.

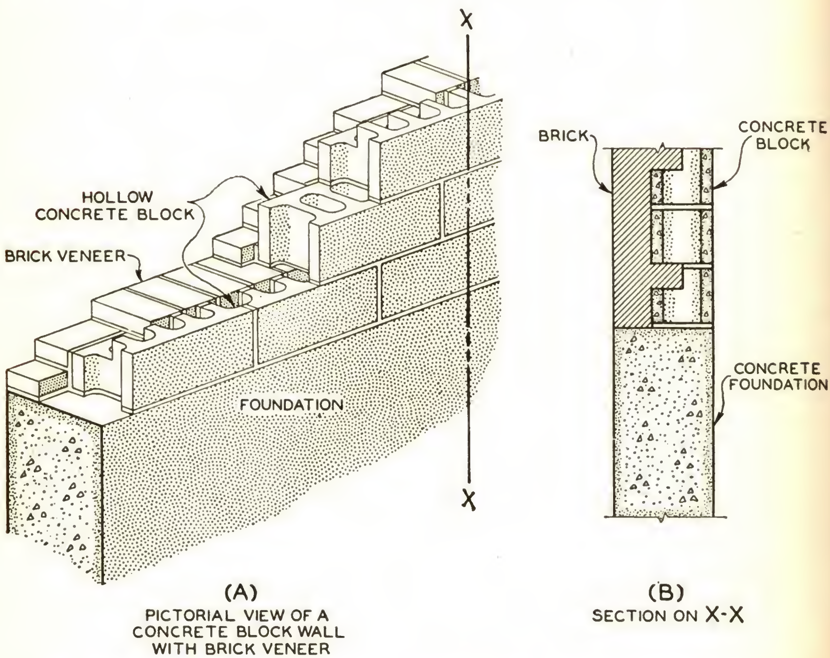


Fig. 18. Pictorial and Section View of a Concrete Block Wall with Brick Veneer

Section View Working Drawings. Figs. 14 through 28 illustrate typical section views of various masonry structural members, all of which are presented so as to show, first, perspective or picture-views and then typical section views. If you will study every one of these illustrations, you will gain a sound understanding of section views and at the same time add materially to your knowledge of many typical masonry structural items. In the following, each of the illustrations will be mentioned and a brief comment given for your guidance.

Concrete Stairs. Imagine, first, that the stairs shown in (A) of Fig. 14 are cut in half along the line *X-X* and the two halves moved apart. The section view thus created is shown at (B). Next, imagine that the

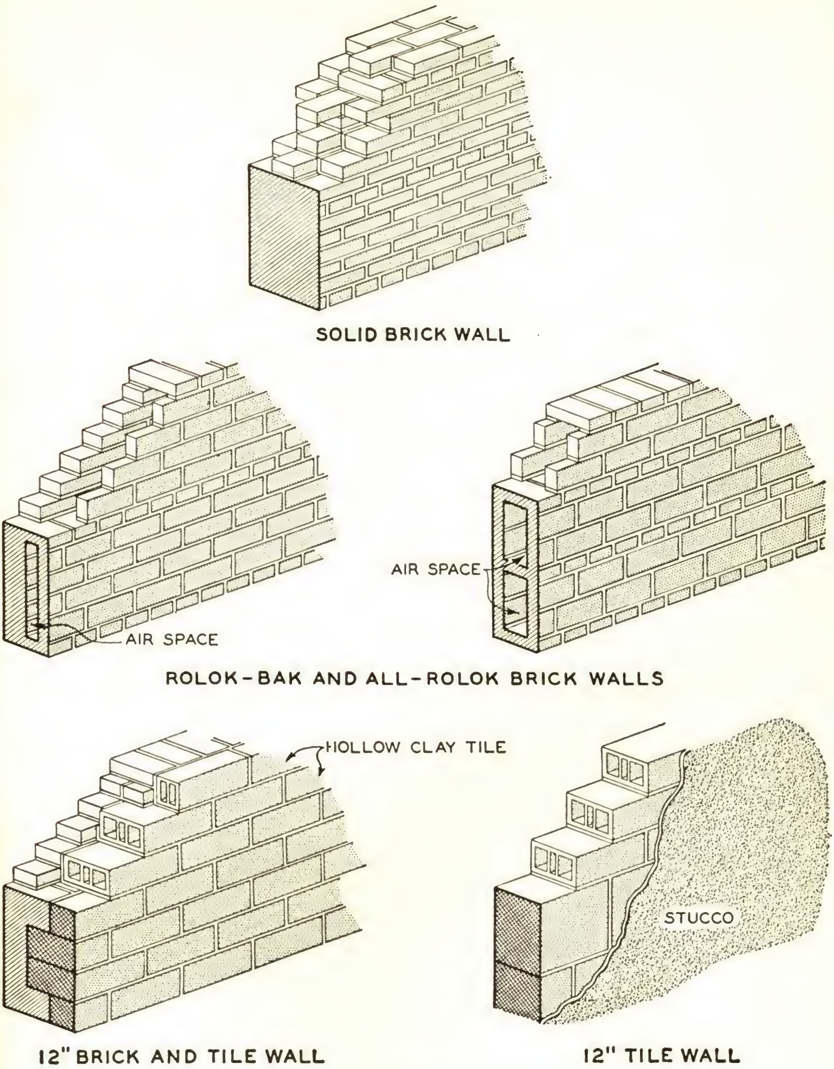


Fig. 19. Pictorial View of Typical Walls and Their Section View Symbols

stairs at (A) are cut in half along the line *Y-Y* and that the bottom half is moved away. The cut surface of the top half, which would then be visible, is shown at (C). By noting points *J, K,* and *L* in illustrations (A), (B), and (C), you can visualize better the section at (C).

FOUNDATIONS. Imagine that the foundation and footing shown at (A) in Fig. 15 could be cut along the line *X-X*. You would then see the end of the wall section *Y* as it is represented at (B), (C), and (D). These three section views illustrate the foundation as it would appear

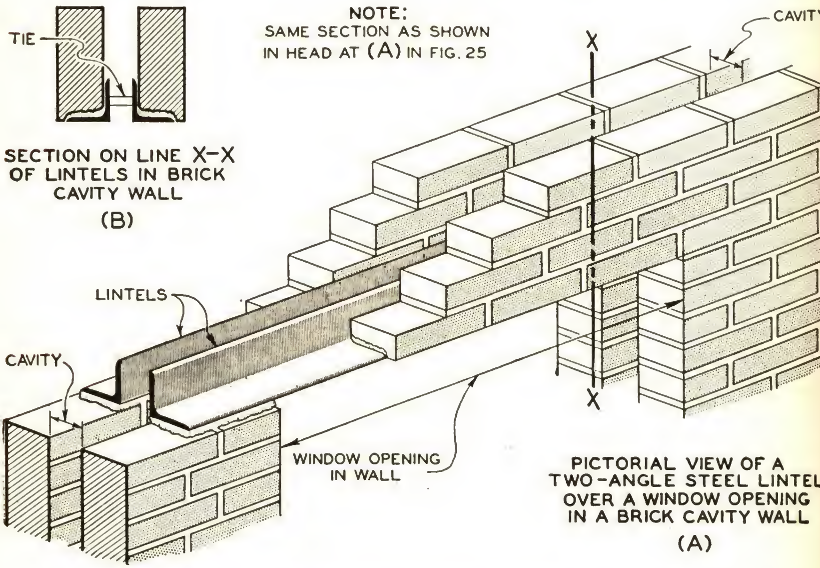


Fig. 20. Pictorial and Section View of a Typical Lintel

if it were made of concrete (B); concrete block (C); and hollow clay tile (D).

WALLS AND FOUNDATIONS. In (A) of Fig. 16 is shown part of a solid brick wall on a concrete foundation. Imagine that both the wall and foundation are cut as in previous examples. Looking at one of the cut surfaces, you would see the section view shown at (B) in Fig. 16. Study the symbols involved as a means of visualizing the section.

Figs. 17 and 18 show other materials used for walls and supported by concrete foundations. The section views will be understandable if you study them as you did for Fig. 16.

Fig. 19 shows section views of solid brick, brick cavity, brick and tile, and solid tile walls. You can visualize them as you did the section views in Figs. 16, 17, and 18.

LINTELS. The pictorial view shown in (A) of Fig. 20 will give you a

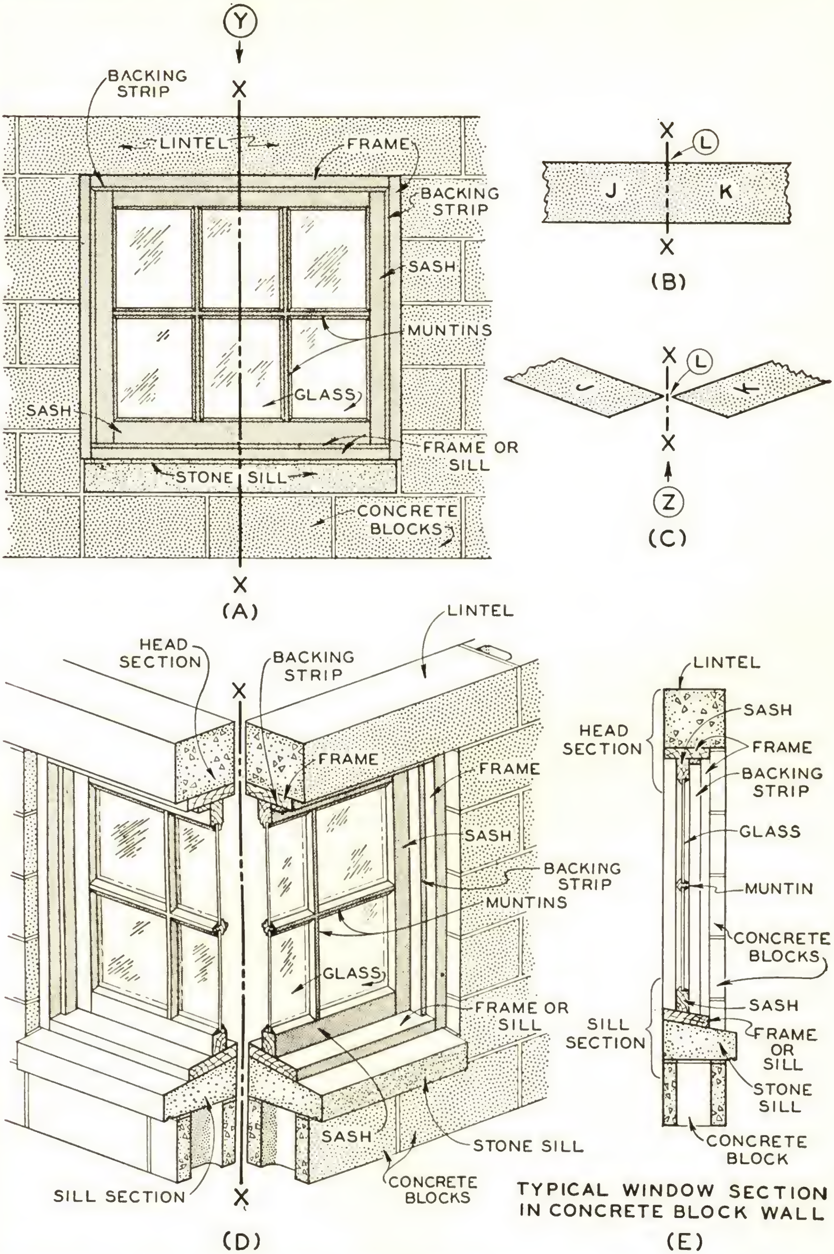
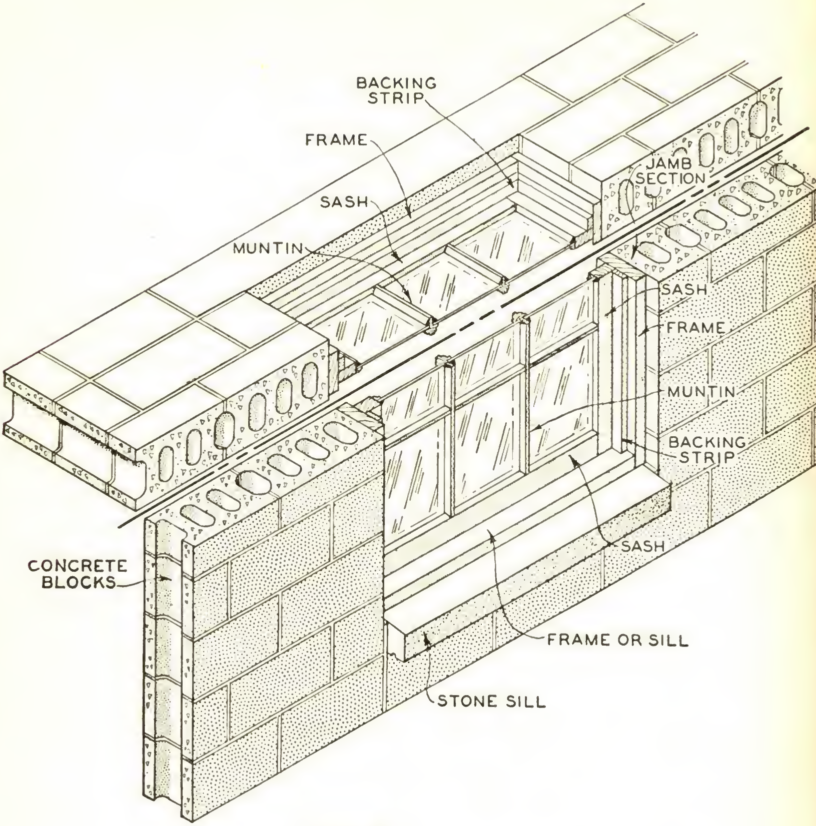
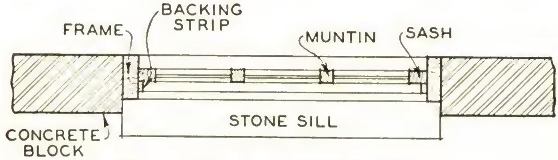
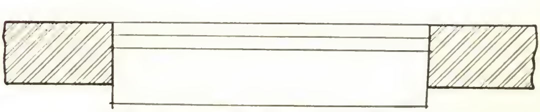


Fig. 21. How to Visualize the Section View of a Window in a Concrete Block Wall





PLAN VIEW WINDOW SYMBOL



SIMPLIFIED PLAN SYMBOL

Fig. 22. How to Visualize the Section View of a Window Jamb in a Concrete Block Wall

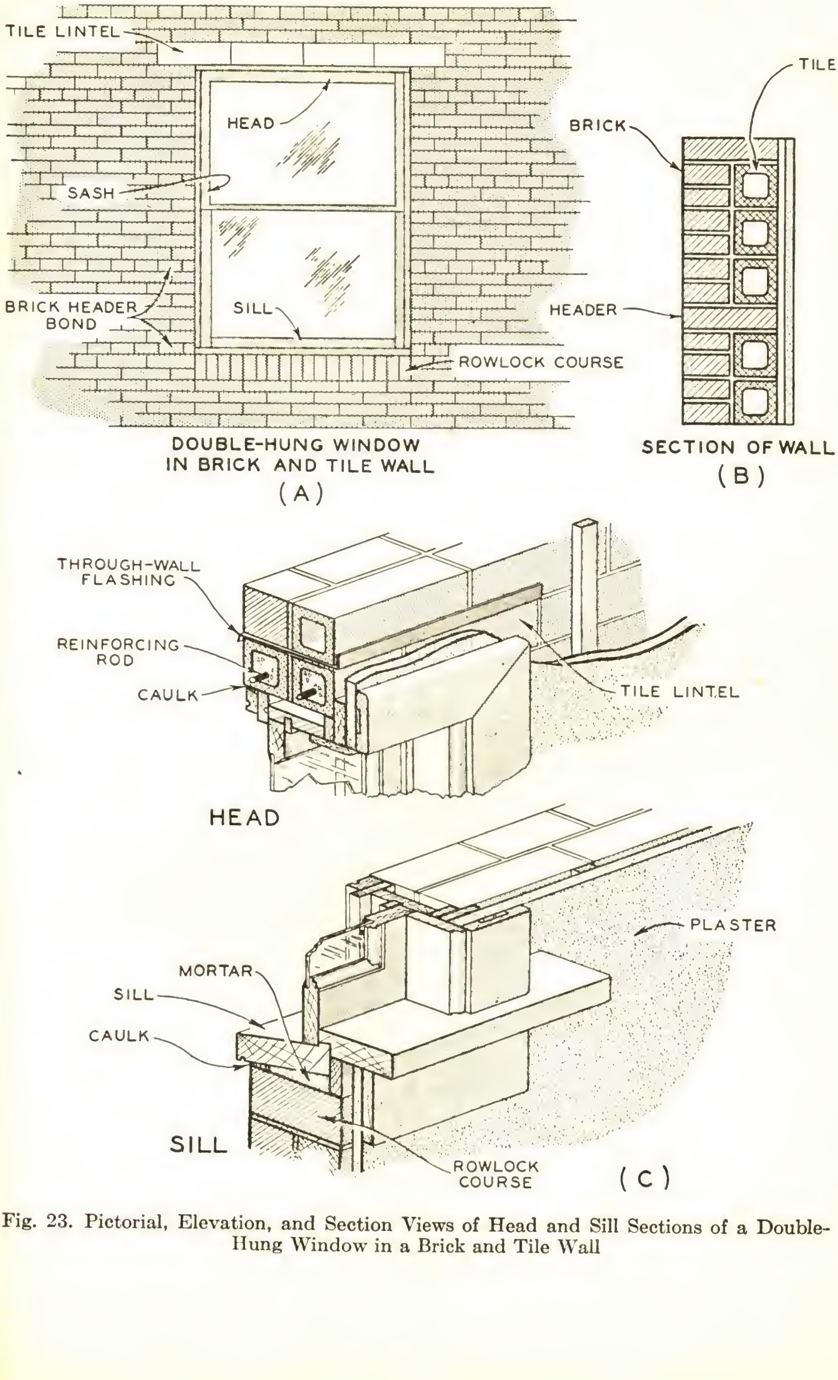


Fig. 23. Pictorial, Elevation, and Section Views of Head and Sill Sections of a Double-Hung Window in a Brick and Tile Wall

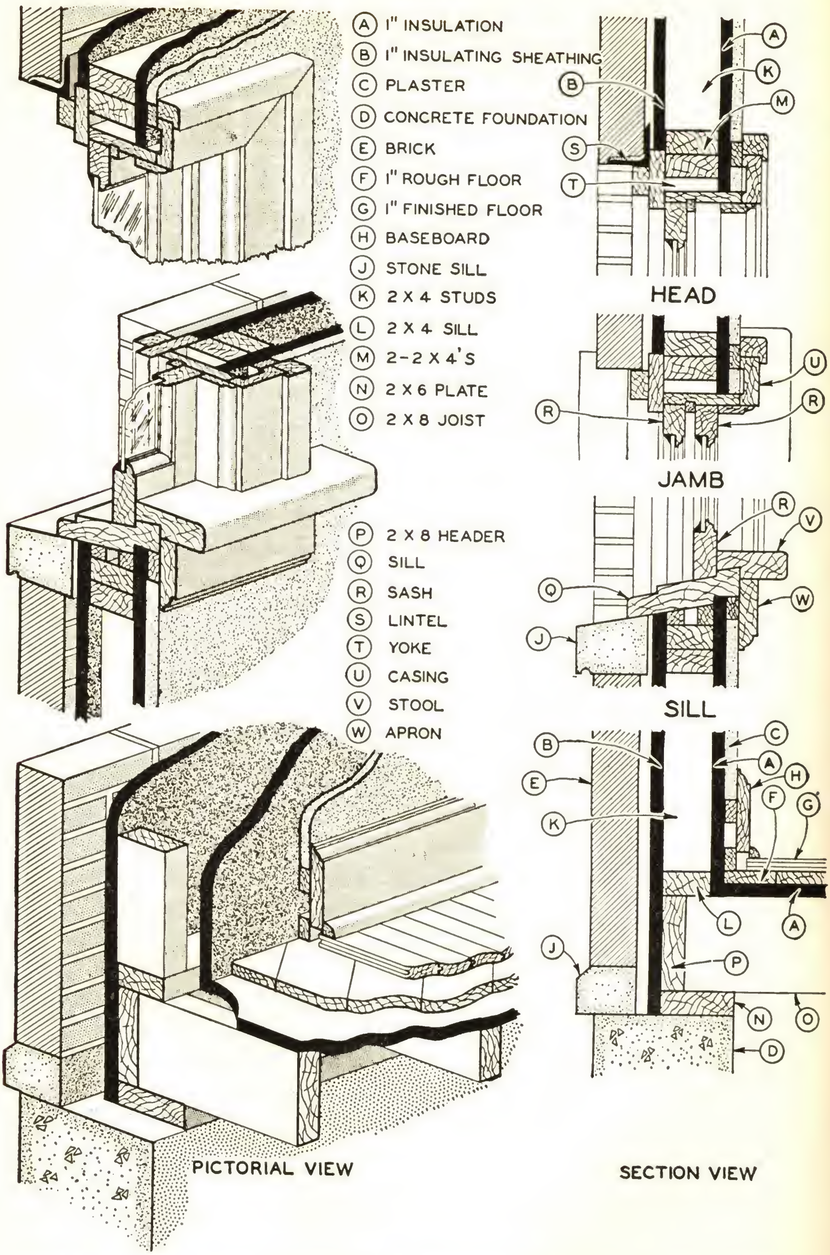


Fig. 24. Pictorial and Section View of a Window in a Brick Veneer on Frame Wall

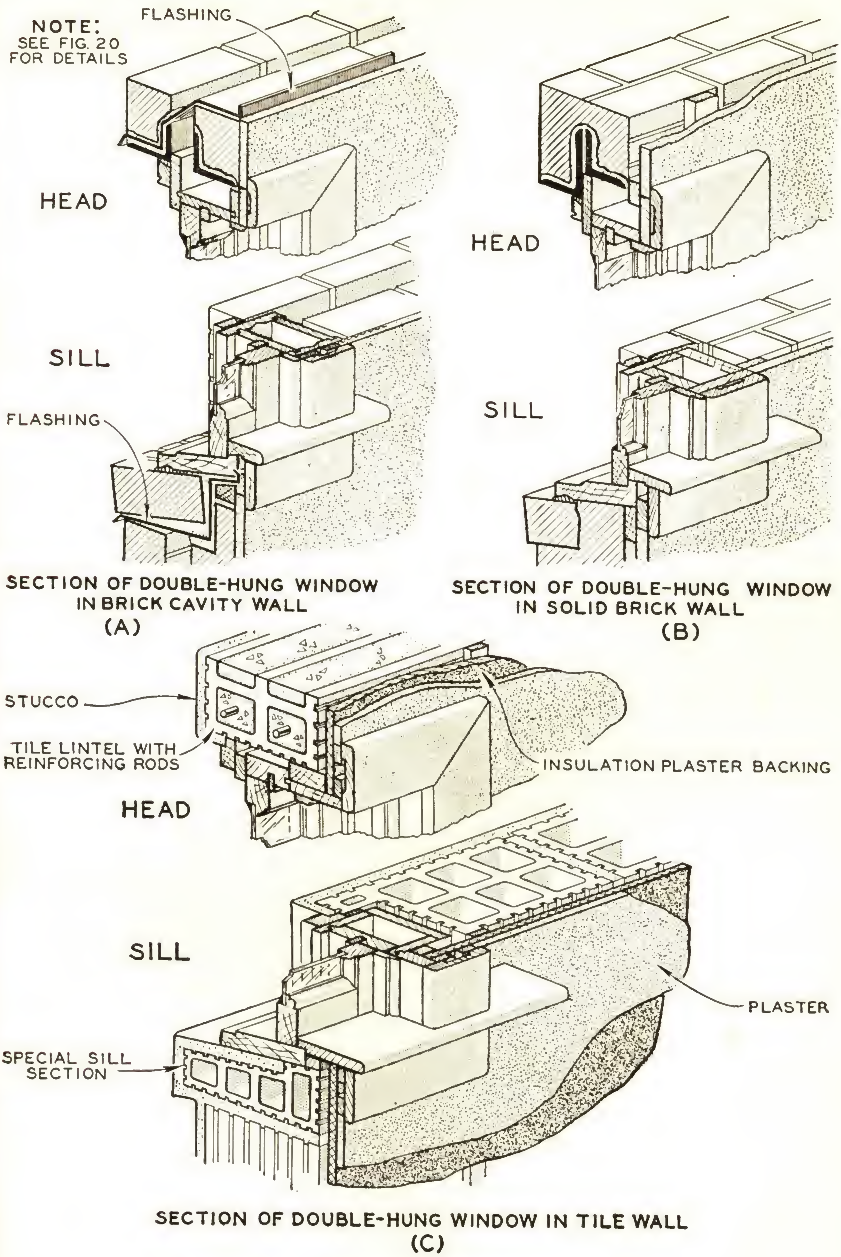


Fig. 25. Pictorial Views of Windows in Masonry Walls

good idea how steel angles are employed to support walls over window openings. Imagine the part of the wall over the opening to be cut on line *X*-*X*. The section you would see is as shown in (B). This is a typical section view of a lintel.

WINDOW. The simple window shown in the elevation view in (A) of Fig. 21 is the same window as required for the milkhouse in Figs. 5 and 10 and is given here to aid visualization.

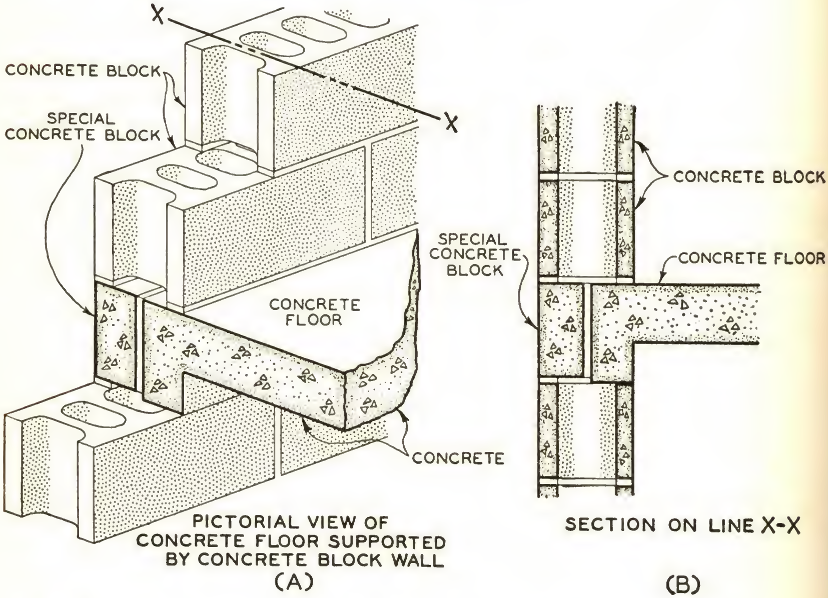


Fig. 26. Pictorial and Section View of a Concrete Floor Supported by a Concrete Block Wall. Note the special concrete block used at the floor level to preserve the bond and exterior appearance

Imagine that this window could be cut in half at the line *X*-*X*. Note sketches (B) and (C). The sketch in (B) is a view of the wall which contains the window as seen from a point directly above, shown by arrow *Y* at the top of sketch (A). Now imagine that you could cut the wall at line *X*-*X* and swing parts *J* and *K* back as has been done in (C), with point *L* acting as a hinge in (C). Finally, imagine that you could look at the cut surfaces of the wall as from point Z. If you imagine the same situation for the wall and window at (A) you will see a pictorial presentation of the section view at (D). This double sec-

tion view will help you visualize the various parts of windows as shown in true section views. In (E) is shown a standard section view of a simple window in a concrete block wall. Study this illustration until you understand it because it is an important type of section.

Fig. 22 is a similar illustration except that the window and wall (the same as in Fig. 21) are cut horizontally to help you visualize what window symbols (see Fig. 8) really are.

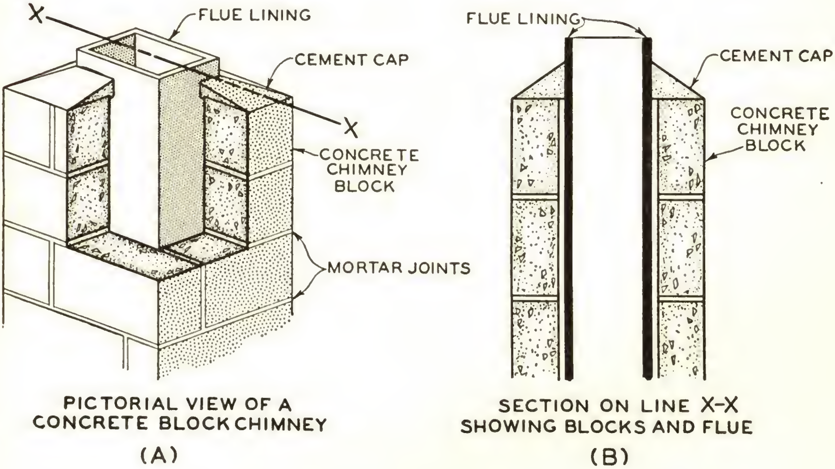


Fig. 27. Pictorial and Section View of a Concrete Block Chimney

Fig. 23 is a more complicated type of window in a brick and tile wall. An elevation view of the window and the wall is shown in (A). In (B) is shown a section view of the wall. If you imagine that this window is cut as was the window in Fig. 22, you can visualize the section view of the wall and window shown at (C).

Brick Veneer. The pictorial view shown in Fig. 24 illustrates a brick veneer wall on frame. With what you have learned in previous illustrations, you should be able to visualize the section view of the wall and of the window.

Fig. 25 shows section views of windows in three different types of masonry walls. Study these sections until you can visualize them easily. Refer to simpler section views if you have any trouble.

As previously mentioned, it is important that you thoroughly

understand window section views. This understanding can be attained by careful study of all section views shown in the chapter. Once you really understand Figs. 21 and 22 you can, by careful study, also understand the more complicated window section views.

FLOORS. In many instances, concrete floors have their bearing in

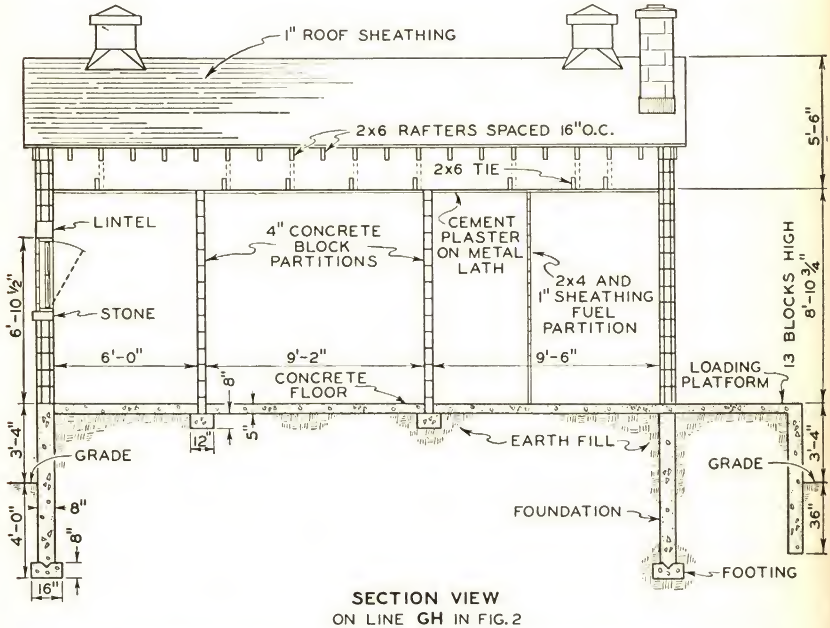


Fig. 28. Section View of the Milkhouse Shown in Figs. 2, 5, 7, and 10

masonry walls. A typical example of this is shown in (A) of Fig. 26. In (B) is shown a section view of the wall and of the floor.

CHIMNEY. The pictorial view in (A) of Fig. 27 shows the chimney required for the milkhouse illustrated in Figs. 5 and 10. This chimney is constructed of concrete blocks and flue lining. The section view shows the construction. Imagine that the chimney could be cut vertically in half, starting at line *X-X*. If one part could be moved away so you could see the cut surfaces, they would look like the section view shown at (B).

BUILDINGS. Refer again to Fig. 2 which is a pictorial view of the milkhouse discussed previously. You will note the two cutting lines,

ABC and *GH*. If the western portion of this house could be removed to show the cut section of the remaining eastern part, the view you would get would be Fig. 28. If you study this section view in conjunction with Figs. 2, 5, and 10, it will make your understanding and visualization of the section view much easier.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

Note: ***Questions 1 through 14 pertain to Fig. 17.***

1. How many exterior door symbols are shown?
Answer. Three.

2. How many exterior window symbols are shown?
Answer. Eight.

3. What size the exterior doors are to be?
Answer. The exterior door size is 3′ 0″ x 6′ 8 inches.

4. What size the interior or partition doors are?
Answer. There are three sizes—3′ 0″ x 6′ 8″, 2′ 0″ x 6′ 8″, and 2′ 4″ x 6′ 8 inches.

5. Where the door is located, the size of which is 2′0″x6′8 inches?
Answer. This is the lavatory door.

6. Where insulation is required?
Answer. In the refrigerator room.

7. What type is specified?
Answer. Rigid type.

8. What the largest window size is and where it is located?
Answer. The largest window is 6′ 8″ wide and is located in the wash room.

9. How many floor drains are required?
Answer. Three drains are required.

10. Where they are located?
Answer. One in the wash room, one in the unloading space, and one in the pasteurizer room.

11. How many treads are shown for the platforms?
Answer. Four treads.

12. What material the interior partitions are to be constructed of?
Answer. Concrete blocks.

13. How many interior window symbols are shown?
Answer. Two.

14. Where the interior windows are located?
Answer. Between the wash room and the room containing the pasteurizer.

15. Where steel lintels are used?
Answer. Over window and door openings in masonry walls.

16. If the jamb of a window is in a vertical or horizontal position?
Answer. Vertical position.

17. Where a parting strip is used?
Answer. It is a part of a double-hung window.

REVIEW QUESTIONS

Note: ***Questions 1 through 8 pertain to Fig. 35.***

1. How many windows are shown in section views?
2. What size are the partition footings?
3. How far above the grade is the concrete floor level?
4. What material is the cool room partition to be made of?
5. How far are the rafters to be spaced?
6. Is a basement specified?
7. What type of ceiling is indicated?
8. Are the windows to swing in or out?

Note: ***Questions 9 through 16 pertain to Fig. 17.***

9. What are the interior dimensions of the loading space?
10. How wide are the treads for the steps?
11. What fixtures are indicated in the lavatory?
12. How thick must the insulation be?
13. What are the exterior dimensions of the chimney?
14. What are the width and length dimensions for the loading platform?
15. How thick are the exterior walls?
16. How thick are the interior partitions?
17. Suppose an interior partition was not dimensioned as to location. How would you determine the necessary dimension?

CHAPTER V

Concrete Masonry

QUESTIONS CHAPTER V WILL ANSWER FOR YOU

1. *What are some of the typical uses of concrete masonry?*
2. *What are the best dimensions for vertical and horizontal joints?*
3. *How do the sizes of concrete blocks affect the locations of doors and windows?*
4. *How would you go about making concrete blocks by the "homemade" method?*
5. *What precautions should be observed and what methods used in painting concrete blocks?*

INTRODUCTION TO CHAPTER V

One of the numerous applications of cement not mentioned in Chapter III is the manufacture of concrete blocks for building purposes. Because of their large size, consistency in design, and uniformity of dimensions, these blocks are perhaps the simplest to lay of the three types of building units to be discussed in this book. It is logical, then, that they are used to initiate you to the problems involved in erecting even a simple wall. The important thing to remember is that the same general rules apply to the laying of clay tile and brick as apply to the laying of concrete blocks.

Following a short introduction to concrete masonry, a description is given of those units most frequently used. You will learn the difference between actual and nominal block sizes and the reason for this manner of specification. You will be told some of the typical uses of concrete masonry. The various surface finishes obtainable in concrete blocks as well as the more common wall patterns are discussed. You will learn block planning, discovering perhaps with surprise, that the actual dimensions of a building as well as the size and location of the doors and windows, are determined by the size of the concrete blocks to be used. You will find described in detail the problems involved in laying blocks at corners, around doors and windows, over lintels, and in partitions. You will learn the importance of maintaining the proper bond at all times. The actual laying of the units is then described and examples given of typical structures encountered on the job.

The importance and value of the many illustrations cannot be overemphasized. These drawings have been prepared carefully from on-the-job problems. All the various stages in the laying of a wall are presented in a series of simple steps which are easily understood by the beginner.

When you have completed the study of this chapter and feel you understand the various situations explained, you will be prepared for the more complicated problems in the following chapters on clay tile and brick.

USE OF CONCRETE MASONRY

The term *concrete masonry* is applied to various sizes and kinds of hollow or solid block, to brick, and to many sizes and kinds of tile-like building units, all of which are molded from concrete and laid by masons. The concrete is made by mixing Portland cement with water and such materials as sand, pebbles, crushed stone, cinders, slag, burned shale or clay, or other types of aggregate.

Concrete masonry is of great interest to masons and others who are concerned with the planning and erecting of such typical structures as residences, stores, garages, theaters, and all types of farm buildings. This type of masonry allows easy planning and quick erection. It can be carried on satisfactorily by masons having little previous experience. It is economical and it is readily adapted to any of the commonly employed styles of architecture.

The purpose of this chapter is to describe some of the more commonly used kinds of concrete units; to explain in greater detail the types of construction they can be used for; to set forth helpful and useful facts relative to textures, colors, wall patterns, mortar, and joints; to show and explain typical details of construction; to show how typical erection is carried on; and to present other miscellaneous items of a helpful nature.

KINDS OF CONCRETE MASONRY UNITS

There are several kinds of concrete masonry units from the standpoint of the materials used in their manufacture and a great many more from the standpoint of shape and size. This chapter treats only of those kinds which are used most generally in the erection of common types of buildings. More detailed information in connection with specific kinds can be obtained from building supply dealers, lumber yards, etc.

Regular Concrete Units. As previously indicated, concrete masonry units can be made using Portland cement, water, sand, and either pebbles or crushed stone. A mixture of this kind produces a heavy-weight unit with excellent strength and durability characteristics and is the particular kind used most generally for exteriors of various types of buildings, especially where the walls must be self-supporting. An-

other reason why the heavyweight units are used most often is because the necessary materials can be assembled more easily in most localities throughout the country. In addition to being strong and durable, the heavyweight units add stability to walls and other structural members, maintain their strengths during and after exposure to fire, and tend to produce soundproof construction.

Lightweight Concrete Units. Concrete masonry units are considerably lighter in weight when made with cinders instead of pebbles or crushed stone. Such units are not as strong as the heavyweight but possess all the other heavyweight qualities and, in addition, have unusually good sound-absorption characteristics which make them exceptionally valuable in the construction of buildings where noise abatement is required. There are other units, such as those bearing the name Haydite,[1] which possess very good sound insulation characteristics as well as a tendency to reduce the flow of heat through them.

SHAPES AND SIZES OF CONCRETE MASONRY UNITS

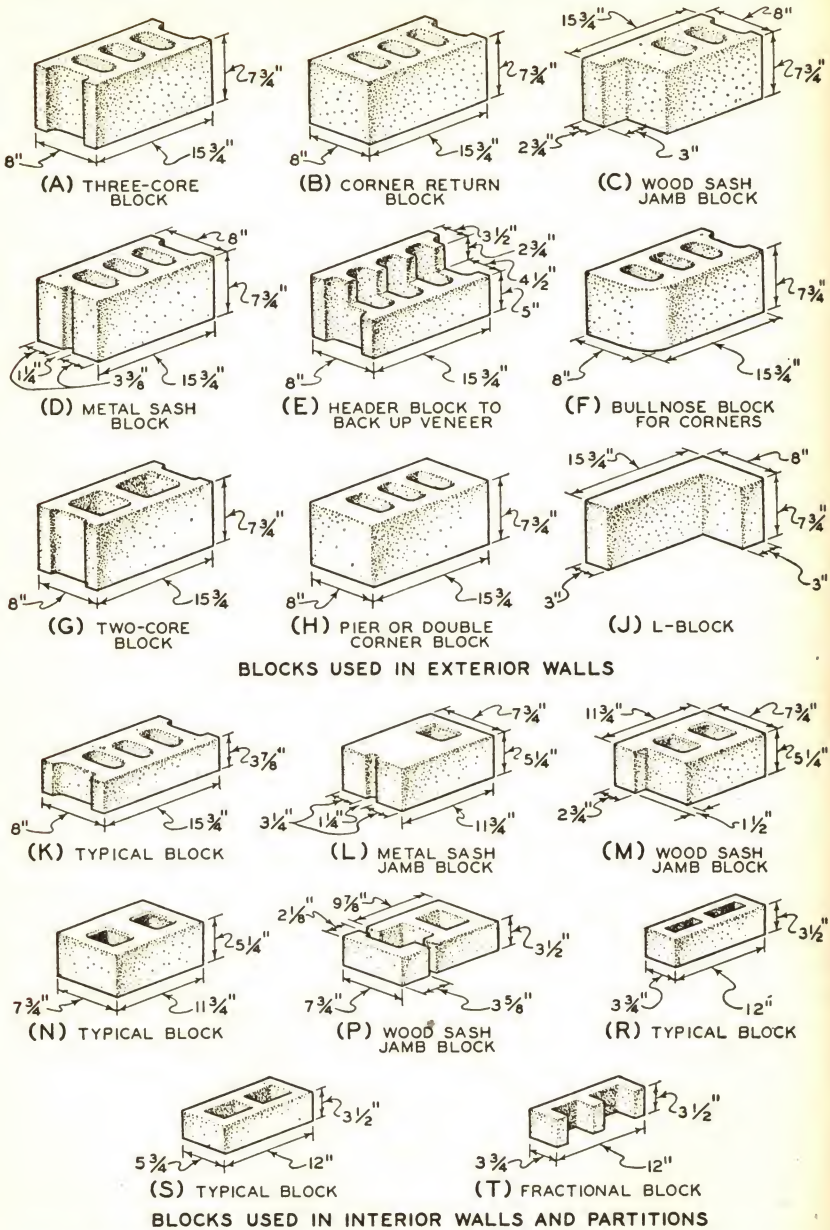
Typical shapes and sizes of concrete masonry units are illustrated and named in Fig. 1. It should be understood that both heavy and lightweight units can be obtained or made in these shapes and sizes and that the typical units illustrated in Fig. 1, constitute only those most commonly used. Many other shapes and sizes are available or can be made. However, those described in this chapter will be ample for the purpose. Most masons refer to concrete masonry units as *concrete blocks* or simply as *block*. Both of these terms are used in the succeeding descriptions.

Three-Core Block. This block, (A) of Fig. 1, is perhaps the most used of all concrete block in building farm buildings, garages, etc., and for all types of buildings where stucco is to be used as exterior surfacing. The use of this block is shown in Figs. 2, 3, and 4, and other succeeding illustrations.

Corner Return Block. This block, (B) of Fig. 1, is used with the block shown in (A) of Fig. 1 for corners and for simple window and door openings, as illustrated in Figs. 2, 3, 4, 33, and 34.

Wood Sash Jamb Block. This block, (C) of Fig. 1, is used along

[1] This is one trade name among several, all of which can be inquired about at building material dealers or lumberyards.



MANY OF THESE BLOCKS ARE MADE IN ONE-QUARTER, ONE-HALF, AND THREE-QUARTER SIZES.

Fig. 1. Standard Concrete Blocks for Use in Walls

with the block shown in (A) and (B) of the same figure around the more elaborate window openings, as shown in (A) of Fig. 13. The recess in the block allows room for the various casing members as, for example, in a double-hung window.

METAL SASH BLOCK. This block, (D) of Fig. 1, is used for window openings in which metal sash is to be employed, as shown in Figs. 4 and 14. The slot in the block allows room to anchor the jamb members of such sash.

HEADER BLOCK. This block, (E) of Fig. 1, is the same as the block shown in (A) except that a shelf has been provided to facilitate bonding it with masonry surfacing, such as illustrated in Fig. 27.

BULLNOSE CORNER BLOCK. This block, (F) of Fig. 1, serves the same purpose as the block shown in (B) but is used where rounded (bullnose) corners are desired.

TWO-CORE BLOCK. This block, (G) of Fig. 1, serves the same purpose as the block shown in (A). The only difference between the two is in the number and shape of the cores. Either block is equally satisfactory for building purposes. Some such block, as illustrated in Fig. 37, have cylindrical cores.

PIER OR DOUBLE CORNER BLOCK. This block, (H) of Fig. 1, is designed for use in laying piers or pilasters, as indicated in Fig. 36, or for any other purpose where both ends of the block would be visible.

L-BLOCK. This block, (J) of Fig. 1, while not as commonly used as the block shown in (A), is employed in much the same manner. When it is used around window and door openings, the 8″ side forms the jambs.

Block (A) through (J) are also made in one-quarter, one-half, and three-quarter sizes.

SPECIAL CONCRETE BLOCKS. The blocks shown in (K) through (T) of Fig. 1, as well as facer units and many other shapes and sizes, are used in laying variously designed walls, some of which are shown in Figs. 22, 28, and 33. Examples of special facer units are shown in (E) of Fig. 20 and in Fig. 21. Special kinds of concrete blocks for use in building chimneys are shown in Fig. 35. The square and rectangular chimney blocks such as (A) of Fig. 35, are generally 6″ thick and the flue lining is built into each block. Such blocks can be purchased having 8½″ square, 8½″ x 13″ rectangular, or 8″ round flues. The hori-

zontal dimensions of these blocks vary from 1′ 5″ to 1′ 10″ square. The smaller solid blocks, such as indicated by (B) in Fig. 25, can be purchased or made in units 3¾″ x 7¾″ x 8¾″, 3¾″ x 7¾″ x 12¾″, and 3¾″ x 7¾″ x 15¾ inches.

Actual and Nominal Block Sizes. The sizes shown in Fig. 1 for the various blocks are the *actual* sizes. For example, the block shown at (A) in Fig. 1 has actual dimensions of 7¾″ x 8″ x 15¾ inches. The finished blocks, when ready for use, have those measurements. However, it is common practice to speak of or designate such blocks in terms of *nominal* dimensions. Using this system, these units are then called 8″ x 8″ x 16″ blocks. This practice is followed in succeeding pages.

The reason for making actual dimensions fractional, such as 15¾″, is that with a ¼″ joint, each block takes up a space in a wall exactly 16″ long. The same explanation holds true for heights such as 7¾ inches. Such dimensions make for easier calculations when figuring the exact lengths and heights for walls and for locating window and door openings.

The standard block sizes do not limit the size of mortar joints to ¼ inch. Joints ⅜″ or ½″ also can be used but the calculations become more difficult when figuring wall lengths, heights, etc.

Not all block manufacturers use the so-called standard sizes shown in Fig. 1. Therefore, it is always wise to ascertain the exact sizes of block to be used before planning wall lengths, heights, etc.

TYPICAL USES OF CONCRETE MASONRY

As previously stated, concrete masonry can be used successfully for many kinds of medium-sized buildings including all types of farm structures. Some of the more specific uses of such masonry are illustrated and explained in the following pages. These illustrations are but typical examples of a great many such possibilities, all of which could not possibly be shown in any one book.

Barns. Fig. 2 shows a medium-sized dairy barn, examples of which can be found on farms all over the country. It contains cow stalls, feeding alleys, litter alley, special pens, feed rooms, a large hay and feed mow, and other features of a standard barn.

The foundations for such a barn may be made of cast-in-place concrete or of concrete masonry. When of concrete masonry, blocks

similar to the block shown at (A) in Fig. 1 are employed. The walls for such a barn also can be constructed of concrete masonry in the form of blocks similar to the block shown at (A) and (B) of Fig. 1. The (A) blocks are used as stretchers between corners and window or door openings, while the (B) blocks are used at corners and around window and door openings. Other details of such typical construction are shown in succeeding pages.

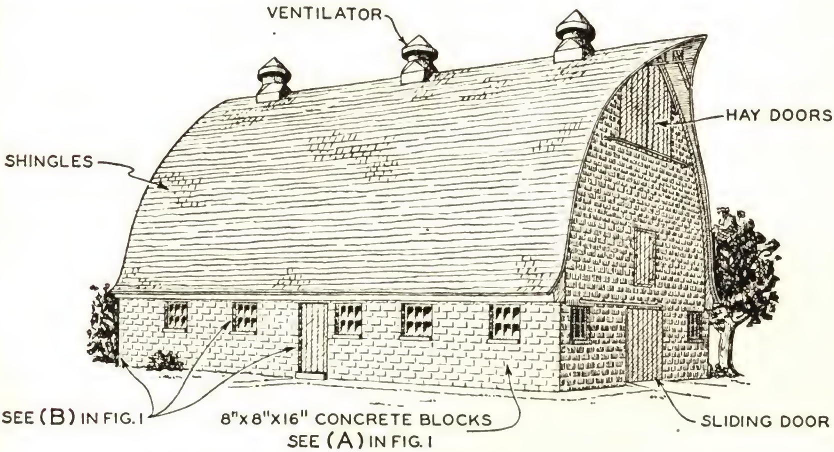


Fig. 2. Dairy Barn Constructed of Concrete Masonry
Courtesy of Portland Cement Association

Small Farm Structures. Fig. 3 shows a pictorial view together with plan and section views of a one-room milkhouse which would suit the needs of most farms.

The foundations, as shown in the section view, can be constructed of concrete blocks similar to the block shown at (A) in Fig. 1. The walls also can be constructed of 8″ x 8″ x 16″ blocks, using (A) blocks (see Fig. 1) as stretchers and (B) blocks (see Fig. 1) at the corners and around the window and door openings. The construction of this milkhouse is explained in greater detail in succeeding pages.

Fig. 4 shows a typical garage and shop building which would be suitable for a farm or other establishment where some repair work must be carried on. Note that in the section plan, the foundations are shown as being concrete while the walls are indicated as 8″ x 8″ x 16″ con-

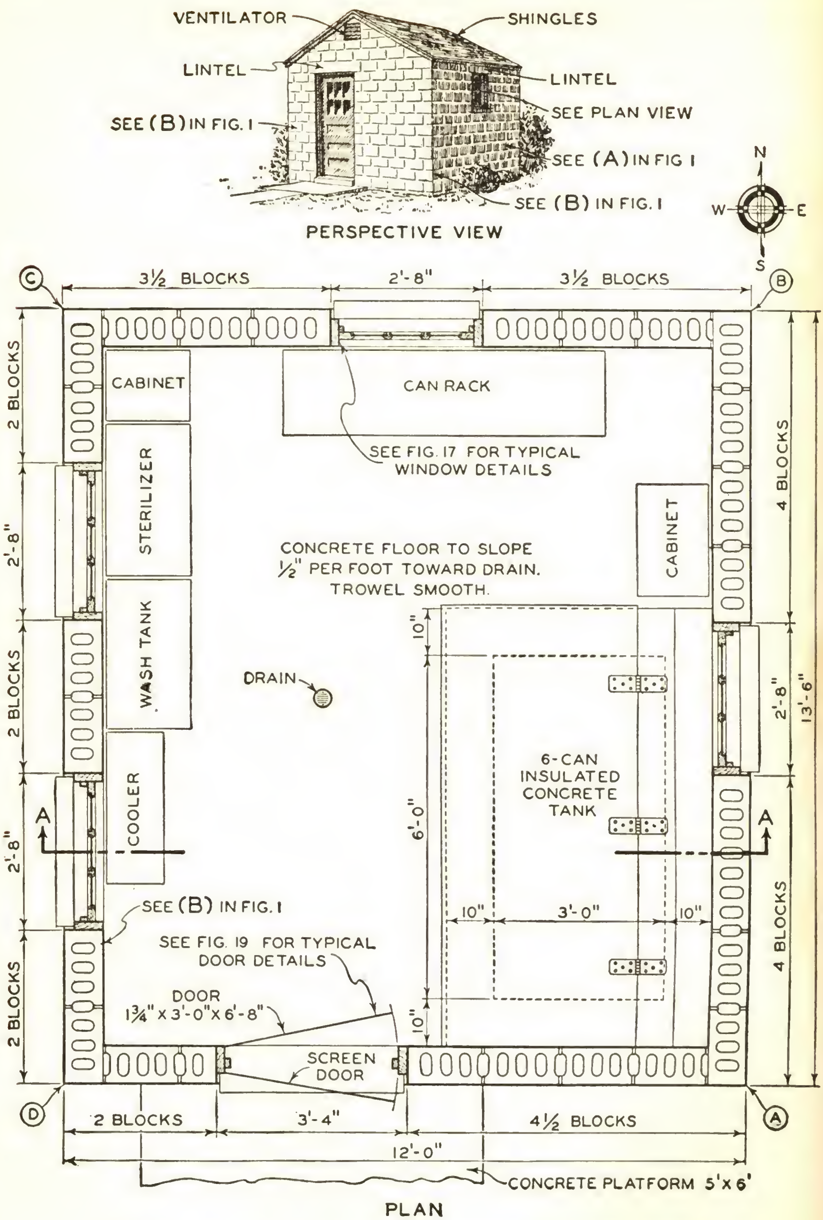


Fig. 3A. One-Room Milkhouse Constructed of Concrete Masonry
(*Courtesy of Portland Cement Association*)

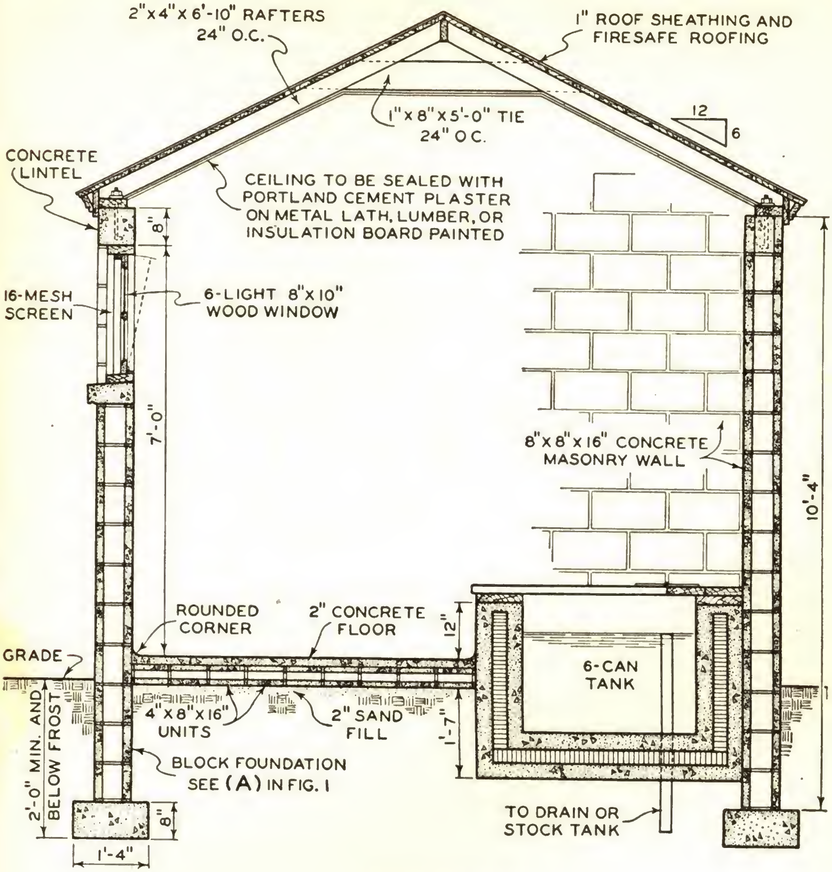
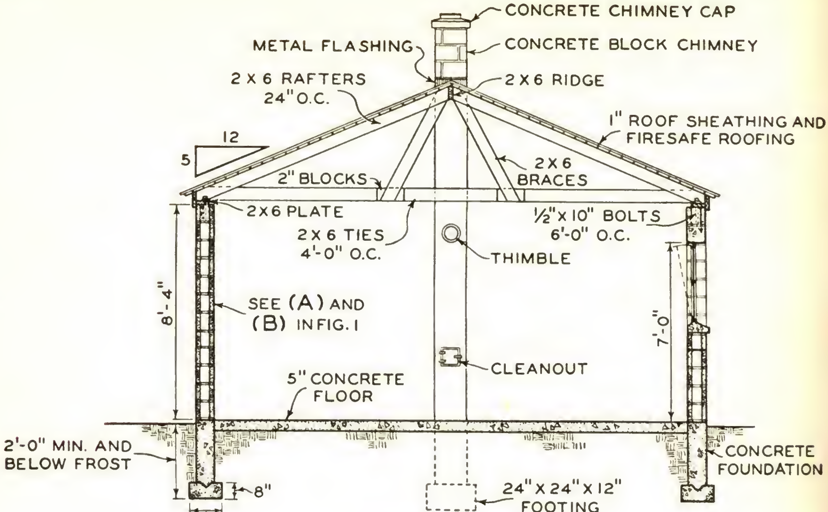


Fig. 3B. Section View of One-Room Milkhouse Constructed of Concrete Masonry
Courtesy of Portland Cement Association

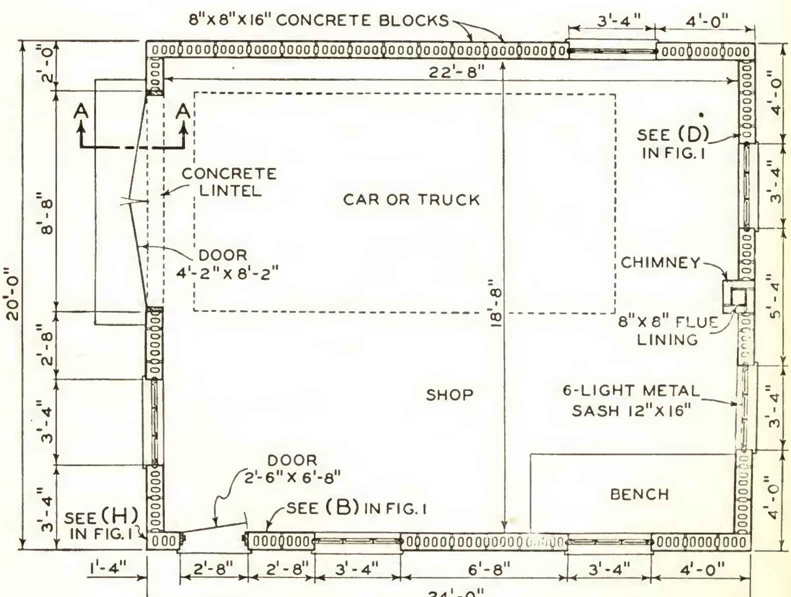
crete blocks. Block planning, bonding, and other details in regard to such construction are shown in succeeding pages.

Residences. Fig. 5 shows a modern residence, the walls of which were constructed of several different shapes and sizes of concrete blocks, all of which makes for a pleasing appearance as well as sound construction. Blocks similar to those shown in Fig. 1 can be used for such walls.

Concrete masonry is an excellent backing for various masonry veneers and wall surfaces. Fig. 27, for example, shows header blocks,



CROSS SECTION



PLAN

Fig. 4A. Plan and Section of a Garage and Shop Constructed of Concrete Masonry
Courtesy of Portland Cement Association

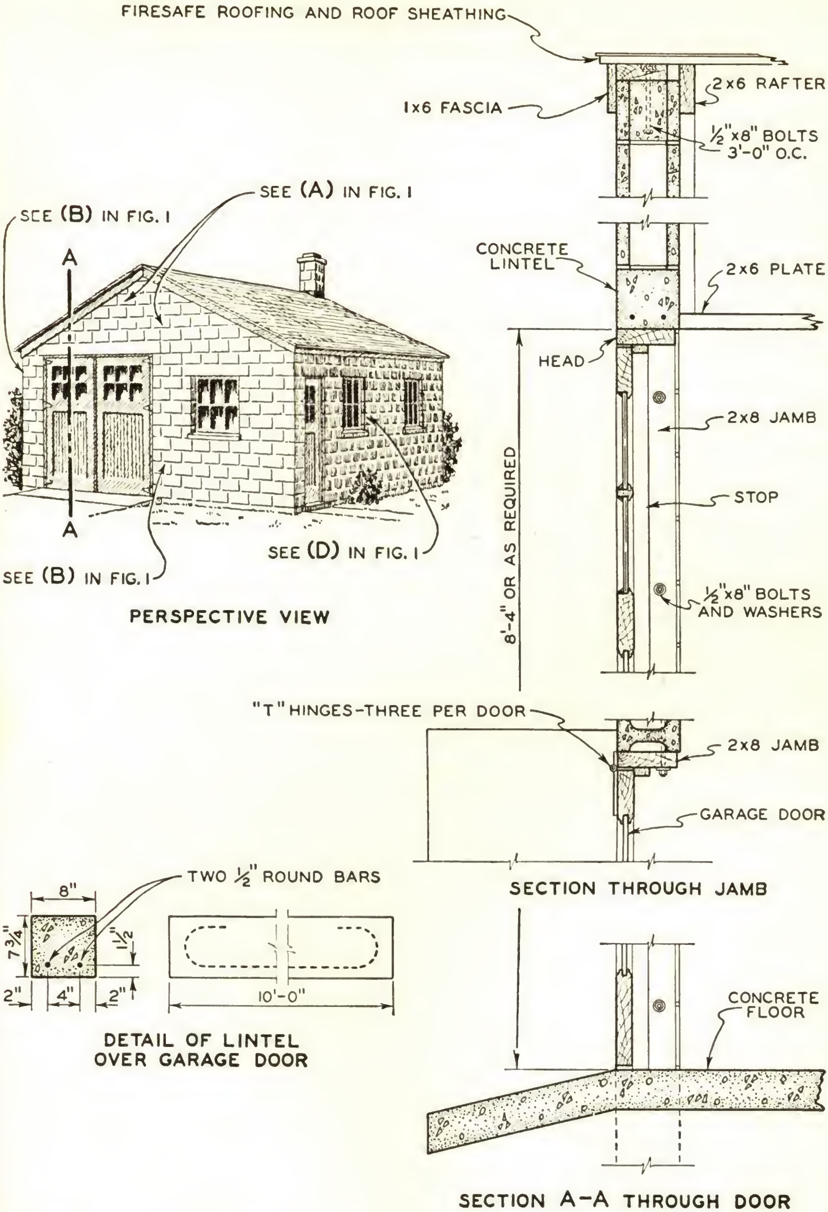


Fig. 4B. Perspective and Section Detail of a Garage and Shop Constructed of Concrete Masonry

Courtesy of Portland Cement Association

as in (E) of Fig. 1, used as backing for brick facing or veneer. This kind of wall can be erected quickly and provides strength and beauty as well. Block walls also are excellent backing for stucco.

Fig. 5. Use of Concrete Masonry for Walls of Residences
Courtesy of Portland Cement Association

SURFACE FINISHES AND COLOR

Concrete blocks can be purchased or made having any one of a variety of surface finishes or textures. Some of the most common finishes or textures and their uses are explained in the following paragraphs.

Plain Finish. When blocks are to be used as backing or where their surfaces are not visible after construction is complete, their surface texture can be left rough or unfinished just as they came from the forms. For such blocks, regular concrete is poured into forms and aside from spading to make sure no voids occur, no further work is done on them. The result is surfaces which are mostly irregular with aggregate showing at one or more places. Their appearance is bad but they are sound and serve their purpose. They are cheaper than blocks having

special finishes or surface textures and make for economy in construction.

Smooth Finish. Blocks used for barns, milkhouses, garages, and other small buildings generally have smooth or fine-grained surface textures. This makes a good appearance, especially when joints are well tooled. Extra steps necessary in the manufacture of smooth-finish blocks are explained in the section of this chapter on homemade blocks. Textures from very fine to semi-rough may be made.

Rough Finish. Rough-surfaced blocks in several varieties also produce beautiful walls. Such surfaces may have the appearance of having been brushed, channeled, combed, or eroded. Many effects can be produced by the use of special forms, special materials, and special handling.

Color. Many manufacturers make blocks in a variety of colors. The colors are achieved by the use of non-fading mineral pigments or by the use of special cement paints. Colored blocks produce pleasing walls, especially for residences.

WALL PATTERNS

Wall patterns or designs may be divided roughly into two general groups which are called *common* and *ashlar*. Both are explained and illustrated in the following paragraphs.

Common Patterns. Perhaps the greatest number of walls are erected using 8″ x 8″ x 16″ blocks such as shown at (A), (B), (C), (D), (H), (K), (L), (M), and (N) of Fig. 1. Fig. 6 shows the most common pattern used in the design and erection of concrete blocks. The blocks are all of the same general size and shape and the vertical joints are staggered. This pattern is the easiest to lay, allows fastest erection, and is generally the cheapest. Walls of this pattern can be made attractive by the use of blocks having smooth,

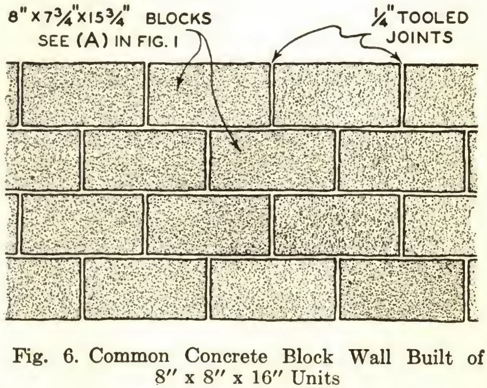


Fig. 6. Common Concrete Block Wall Built of 8″ x 8″ x 16″ Units

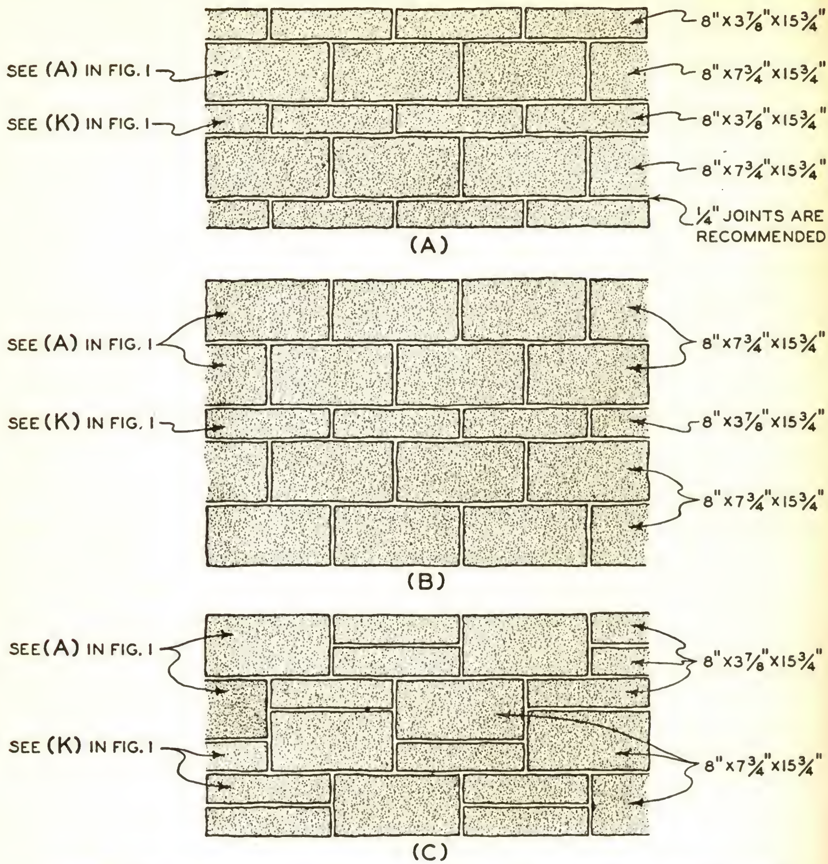


Fig. 7. Three Wall Patterns Obtained by the Use of Two Sizes of Concrete Block

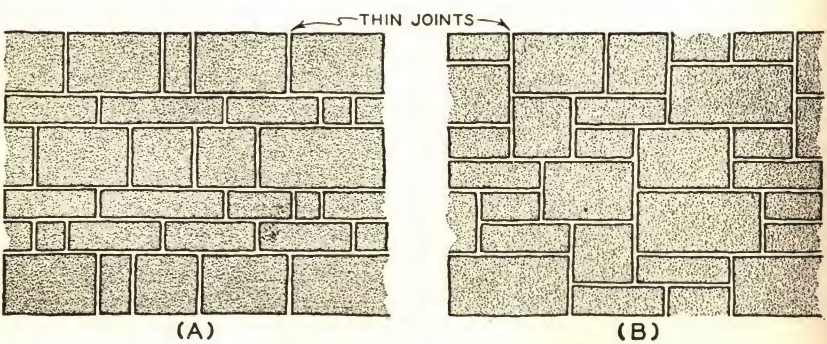


Fig. 8. Example of Coursed Ashlar (A) and Random Ashlar (B)

rough, or colored surfaces laid with well-made mortar joints. Note that the walls shown in Figs. 2, 3, and 4 have the same pattern as shown in Fig. 6.

Fig. 7 illustrates three other common patterns, all of which can be accomplished using two general sizes of block as indicated. The block dimensions shown are the actual sizes. The patterns at (A) and (B) in Fig. 7 are the easiest to lay and the one shown at (C) is really not difficult if care is exercised in laying each block. Patterns like this require carefully tooled mortar joints in order to bring out their natural beauty. Smooth or rough-finish blocks with or without color may be used.

Ashlar Patterns. A more modern development in the concrete masonry field is ashlar patterns which use blocks in a variety of shapes and sizes. Ashlar construction is known as *coursed ashlar* when the various blocks are arranged according to height, to form regular courses in the face of walls. See (A) in Fig. 8. It is called *random ashlar* when several sizes of block are laid up more or less at random. See (B) in Fig. 8. It is called patterned random when the blocks are laid apparently at random, but actually are placed in a definite pattern which is repeated again and again. (See Fig. 9.) Ashlar patterns offer many possibilities for excellent architectural treatment, an example of which is shown in Fig. 5.

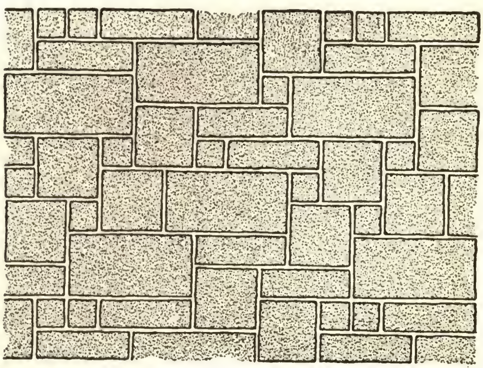


Fig. 9. Patterned Ashlar Where Pattern Repeats in Each Square Yard of Wall

In ashlar design, a great deal can be accomplished by the use of only a few standard sizes of block. For example, in Fig. 9 the patterned random effect is achieved through the use of only four nominal sizes 8″ x 16″, 8″ x 8″, 12″ x 4″, and 4″ x 4 inches. Unless very intricate patterns are specified, no more than four sizes of block are required.

In cases where expense is not an important item, any number of specially made block sizes and shapes can be used. However, this

necessitates special detail drawings and equally special manufacture.

Mortar and Joints. Good mortar and well-made joints are important items in concrete masonry work. Great care should be taken to see that both items are properly made.

MORTAR. A mortar consisting of one part Portland cement, not more than one part lime putty or hydrated lime, and damp, loose sand equal to not more than three times the combined parts of cement and lime, is one recommendation for good mortar in average construction. When a mortar of maximum strength is required for walls, pilasters, or columns which support heavy loads or are subject to heavy winds or earthquakes, a mortar consisting of one part Portland cement and not more than three times as much damp, loose sand is recommended.

Caution. The use of sand taken from ordinary excavations should be avoided. Such sand is likely to contain a high percentage of soil which cuts down the strength of mortar made with it. Good mortar sand should be free from soil or other materials.

JOINTS. All vertical joints should average 1/4″ to 3/8″ in thickness. Thicker joints are not as strong and reduce the strength of walls. Horizontal or bed joints should be not more than 1/2″ thick and should average nearer 3/8″ in thickness. However, joints up to 3/4″ are not too objectionable.

TYPICAL CONCRETE MASONRY CONSTRUCTION DETAILS

In order to understand how various concrete masonry walls are actually designed and erected, it is necessary to be familiar with the common details of such construction work. The following explanations include the most commonly encountered details in average concrete masonry design and construction.

Block Planning. The most economical concrete masonry walls, examples of which are shown in Figs. 3 and 4, are constructed using two standard blocks, namely, those shown in (A) and (B) of Fig. 1. Good construction demands that joints be staggered as indicated in Fig. 6. Good appearance demands that the blocks be used uniformly in all courses. To comply with these demands, the architect or any other person who plans concrete masonry walls must carefully con-

sider the lengths of the blocks plus mortar joints in deciding on the lengths of walls and the location and size of window and door openings. Heights of walls and heights of window and door openings also must be considered in connection with the heights, plus mortar joints, of the blocks.

Suppose, for example, that in planning a small building whose

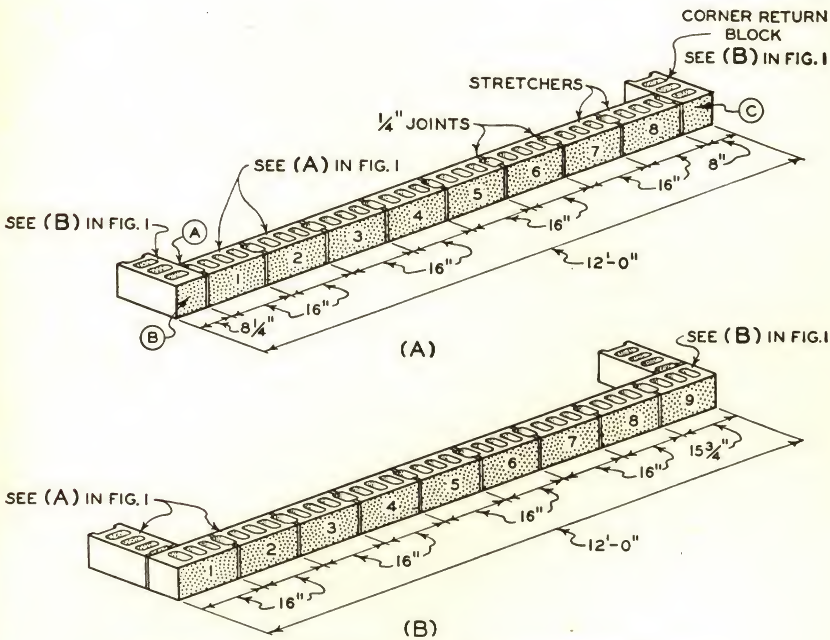


Fig. 10. First and Alternate Courses of a Well-Planned Block Wall

walls are to be constructed of 8″ x 8″ x 16″ concrete blocks, it is desirable from the architectural standpoint, to have one of the walls exactly 12′ 0″ long. Before this length can be definitely decided upon, the lengths of the blocks plus mortar joints must be considered.

Each ordinary stretcher block, (A) in Fig. 1, is *actually* 15¾″ long. Adding a ¼″ mortar joint to a stretcher makes it exactly 16″ long. Corner return blocks, (B) in Fig. 1, are *exactly* 8″ wide.

One course of the wall in question is shown in (A) of Fig. 10.

It can be seen that 2 corner return blocks and 8 stretchers fit nicely into the 12′0″ wall length. This was determined in advance as follows:

The 12′0″ dimension equals 144 inches. There must be a corner return at each corner. These are each 8″ wide and make a total of 16″ which, subtracted from 144″, leaves a remainder of 128 inches. Dividing 128″ by 16″ gives a quotient of exactly 8. In other words, 8 stretcher blocks, allowing ¼″ joints, fit between the two corner returns as shown in (A) of Fig. 10. However, these calculations do not take the joint at *A* into consideration. This is not serious, for each of the other joints can be made a trifle smaller so as to allow room for it.

To check the block layout shown in (A) of Fig. 10, note the small dimensions shown. Adding these will equal 12′¼″ or 144¼ inches. There are eight stretchers which, with their ¼″ mortar joints, equal 16″ each. Eight times 16 is 128 inches. The corner return at *B* plus the extra joint makes 8¼″ which, when added to the 8″ corner return at *C*, gives 16¼ inches. Adding 16¼″ and 128″ gives a total of 144¼″, which is just ¼″ more than 12′0 inches. The extra ¼″ is absorbed by the other 8 joints as was pointed out in the last paragraph.

The next regular course above the course shown in (A) of Fig. 10 would have the corner returns laid in the opposite direction, as indicated in (B) of Fig. 10. In this course there are 9 stretches (including the corner returns because they are in line with the regular stretchers) and 8 joints. There is one less joint than in the under course shown in (A). Therefore, one stretcher (No. 9) is only 15¾″ long. The length can be checked by multiplying 16″ by 8 and adding 15¾″, which gives a total of 143¾ inches. In this course, each of the 8 joints must have a little added to it to make up the necessary ¼ inch.

Note: Instead of dividing reductions or increases among all joints, masons generally reduce or increase one or two joints. This is much easier and quicker and where only small reductions or increases are involved, is hardly noticeable.

As a further example, suppose that from the architectural standpoint it was desirable to have a wall 12′6″ long instead of the 12′0″ length previously discussed.

Fig. 11 shows one course of such a wall and how one block (see X) would have to be a half block in order to fill out the required length of the wall. The small dimensions total 150″ or 12′ 6 inches. The use of half blocks, such as the block shown at X, ruins the appearance of walls and should be avoided. Therefore, the extra 5¾″ either must be absorbed by the other 9 joints, or the dimension changed to 12′ 0″ or made large enough to accommodate another full block.

If the 5¾″ is divided among the remaining 9 joints (there would be 9 joints without block X) each joint would be increased by over ½ inch. This would make all joints more than ¾″ thick. This is

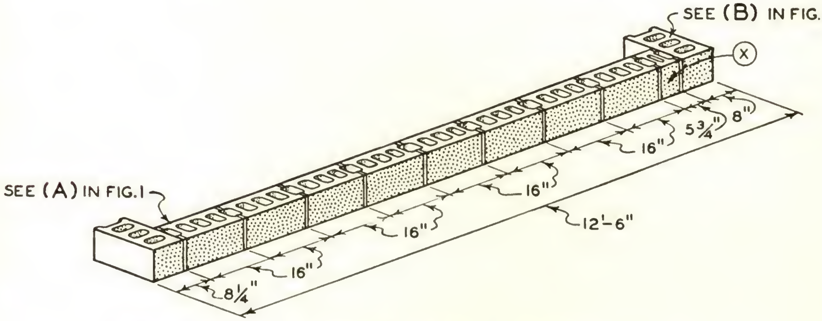


Fig. 11. Bonding Problems Result from a Poorly Planned Wall

greater than the ⅜″ maximum allowed for vertical joints. Therefore, the dimension must be changed to accommodate the block sizes.

Following this procedure, the length dimensions for the walls of each job should be carefully considered no matter what shapes and sizes of block are to be used. The heights of block walls should be checked with equal exactness. Height consideration is much easier as it is only necessary to add the height of the block plus horizontal mortar joint for the various courses.

The location and size of windows in concrete block walls require careful consideration in order to avoid the cutting of blocks. Note the window opening shown in Fig. 12. It can be seen that the opening width C, the height B, and the height of the bottom of the opening above the foundation A, are all in terms of an exact number of blocks horizontally and vertically. This is the ideal situation which should be carefully planned for any window opening in a block wall.

To accomplish ideal window planning in block walls, the size of windows must be selected to accommodate the blocks both horizontally and vertically. Any deviation from this rule results in unsightly walls, occasionally poor bond between various blocks, and always increased labor costs.

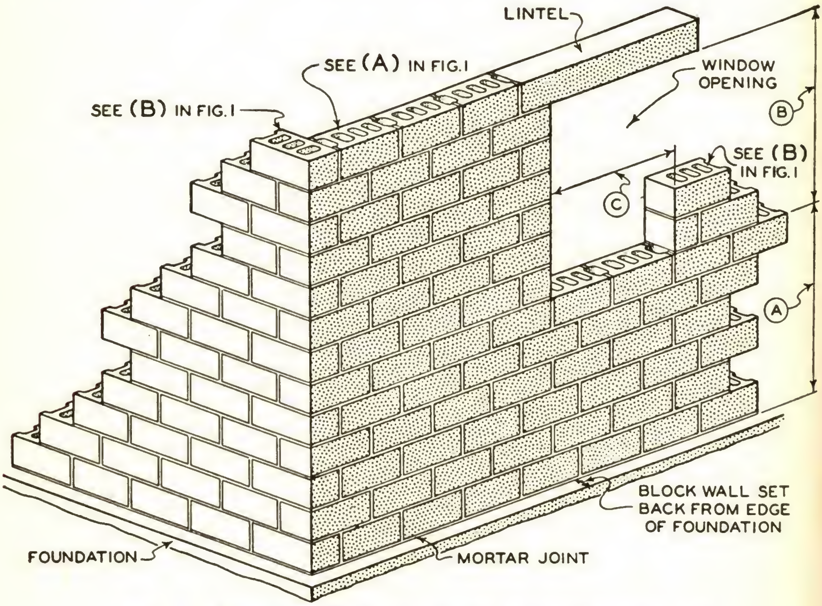


Fig. 12. Locations of Window Openings Must Be Planned Also

The location and size of doors in concrete block walls require the same considerations necessary for windows.

The masonry work on concrete block walls should never be started until the mason doing the work has carefully checked all of these items. The time thus spent will be of much value and will save a great deal of extra labor, expense, and disappointment.

Tables 1 and 2 give helpful information for planning the lengths and heights of block walls.

Window Details. There are many varieties of windows from the standpoint of the size, shape, and assembly of their various parts, such as casings, sash, stools, aprons, stops, etc. However, all varieties are nearly enough alike so that a few typical examples will amply illustrate the general details.

As far as a mason is concerned when laying a concrete block wall, a window has three principal parts, namely, the *head, jambs,* and *sill.* The head, as the name implies, is the horizontal top of the window, the jambs are the vertical sides, and the sill is the horizontal bottom. All three of these principal parts are made up of a number of lesser parts.

TABLE I. LENGTH OF CONCRETE MASONRY WALLS BY STRETCHERS

For standard units 15¾″ long and half units 7¾″ long with ¼″, ⅜″ and ½″ head joints. Length measured from outside edge to outside edge of units.

No. of Stretchers	Length of Concrete Masonry Walls for Given Thickness of Mortar in Head Joint		
	¼″	⅜″	½″
1	1′ 3¾″	1′ 3¾″	1′ 3¾″
1½	1′ 11¾″	1′ 11⅞″	2′ 0″
2	2′ 7¾″	2′ 7⅞″	2′ 8″
2½	*3′ 4″	3′ 4″	3′ 4¼″
3	4′ 0″	4′ 0″	4′ 0¼″
3½	4′ 8″	4′ 8⅛″	4′ 8½″
4	5′ 4″	5′ 4⅛″	5′ 4½″
4½	6′ 0″	6′ 0¼″	6′ 0¾″
5	6′ 8″	6′ 8¼″	6′ 8¾″
5½	7′ 4″	7′ 4⅜″	7′ 5″
6	8′ 0″	8′ 0⅜″	8′ 1″
6½	8′ 8″	8′ 8½″	8′ 9¼″
7	9′ 4″	9′ 4½″	9′ 5¼″
7½	10′ 0″	10′ 0⅝″	10′ 1½″
8	10′ 8″	10′ 8⅝″	10′ 9½″
8½	11′ 4″	11′ 4¾″	11′ 5¾″
9	12′ 0″	12′ 0¾″	12′ 1¾″
9½	12′ 8″	12′ 8⅞″	12′ 10″
10	13′ 4″	13′ 4⅞″	13′ 6″
10½	14′ 0″	14′ 1″	14′ 2¼″
11	14′ 8″	14′ 9″	14′ 10¼″
11½	15′ 4″	15′ 5⅛″	15′ 6½″
12	16′ 0″	16′ 1⅛″	16′ 2½″
12½	16′ 8″	16′ 9¼″	16′ 10¾″
13	17′ 4″	17′ 5¼″	17′ 6¾″
13½	18′ 0″	18′ 1⅜″	18′ 3″
14	18′ 8″	18′ 9⅜″	18′ 11″
14½	19′ 4″	19′ 5½″	19′ 7¼″
15	20′ 0″	20′ 1½″	20′ 3¼″
20	26′ 8″	26′ 10⅛″	27′ 0½″
25	33′ 4″	33′ 6¾″	33′ 9¾″
30	40′ 0″	40′ 3⅜″	40′ 7″
35	46′ 8″	47′ 0″	47′ 4¼″
40	53′ 4″	53′ 8⅝″	54′ 1½″
45	60′ 0″	60′ 5¼″	60′ 10¾″
50	66′ 8″	67′ 1⅞″	67′ 8″

*By increasing the thickness of only two of the head joints by ⅛″ each the wall lengths from this point down in this column are multiples of 8″ as shown. A little attention to these details will greatly simplify wall layout.

In (A) and (B), of Fig. 13, are shown section views of heads, jambs, and sills for two slightly different varieties of windows.

Window (A) has a head section which consists of a reinforced

concrete lintel plus the casings, stops, parting slip, and other members of the horizontal top of the window. The jamb section consists of a wood sash jamb block, see (C) in Fig. 1, plus ground, casings, stop, etc. The sill section consists of a precast lug-type concrete sill plus the wood sill, nailing strips, apron, stool, etc. The various casings, stops, etc., can be examined at any lumber yard where ready-made window casings are for sale.

Window (B) has a head section which consists of a reinforced, precast concrete split lintel plus the casings, yoke, etc. The jamb section consists of a corner return block (see (B) in Fig. 1) plus the usual casings and other items described for window (A). The sill section consists of a precast, concrete slip sill plus the other items mentioned for window (A).

The sections at both (A) and (B) illustrate the use of two common kinds of concrete lintels, two common kinds of jamb blocks, and

TABLE II. HEIGHT OF CONCRETE MASONRY CONSTRUCTION BY COURSES

For concrete masonry units 7½" to 8" in height laid with ⅜" and ½" mortar joints. Height measured from bottom of mortar joint to bottom of mortar joint.

HEIGHT OF UNIT	7½"	7⅝"	7⅝"	7¾"	7¾"	7⅞"	7⅞"	8"
JOINT THICKNESS	½"	⅜"	½"	⅜"	½"	⅜"	½"	⅜"
NO. OF COURSES								
1	8"		8⅛"		***8¼"**		8⅜"	
2	1′ 4"		1′ 4¼"		**1′ 4½"**		1′ 4¾"	
3	2′ 0"		2′ 0⅜"		**2′ 0¾"**		2′ 1⅛"	
4	2′ 8"		2′ 8½"		**2′ 9"**		2′ 9½"	
5	3′ 4"		3′ 4⅝"		**3′ 5¼"**		3′ 5⅞"	
6	4′ 0"		4′ 0¾"		**4′ 1½"**		4′ 2¼"	
7	4′ 8"		4′ 8⅞"		**4′ 9¾"**		4′ 10⅝"	
8	5′ 4"		5′ 5"		**5′ 6"**		5′ 7"	
9	6′ 0"		6′ 1⅛"		**6′ 2¼"**		6′ 3⅜"	
10	6′ 8"		6′ 9¼"		**6′ 10½"**		6′ 11¾"	
11	7′ 4"		7′ 5⅜"		**7′ 6¾"**		7′ 8⅛"	
12	8′ 0"		8′ 1½"		**8′ 3"**		8′ 4½"	
13	8′ 8"		8′ 9⅝"		**8′ 11¼"**		9′ 0⅞"	
14	9′ 4"		9′ 5¾"		**9′ 7½"**		9′ 9¼"	
15	10′ 0"		10′ 1⅞"		**10′ 3¾"**		10′ 5⅝"	
16	10′ 8"		10′ 10"		**11′ 0"**		11′ 2"	
17	11′ 4"		11′ 6⅛"		**11′ 8¼"**		11′ 10⅜"	
18	12′ 0"		12′ 2¼"		**12′ 4½"**		12′ 6¾"	
19	12′ 8"		12′ 10⅜"		**13′ 0¾"**		13′ 3⅛"	
20	13′ 4"		13′ 6½"		**13′ 9"**		13′ 11½"	
25	16′ 8"		16′ 11⅛"		**17′ 2¼"**		17′ 5⅜"	
30	20′ 0"		20′ 3¾"		**20′ 7½"**		20′ 11¼"	
35	23′ 4"		23′ 8⅜"		**24′ 0¾"**		24′ 5⅛"	
40	26′ 8"		27′ 1"		**27′ 6"**		27′ 11"	
45	30′ 0"		30′ 5⅝"		**30′ 11¼"**		31′ 4⅞"	
50	33′ 4"		33′ 10¼"		**34′ 4½"**		34′ 10¾"	

*Dimensions in bold face are also heights of standard concrete masonry backup course for standard face brick laid flat with ½" mortar joints and headers every sixth course as shown in Fig. 30.

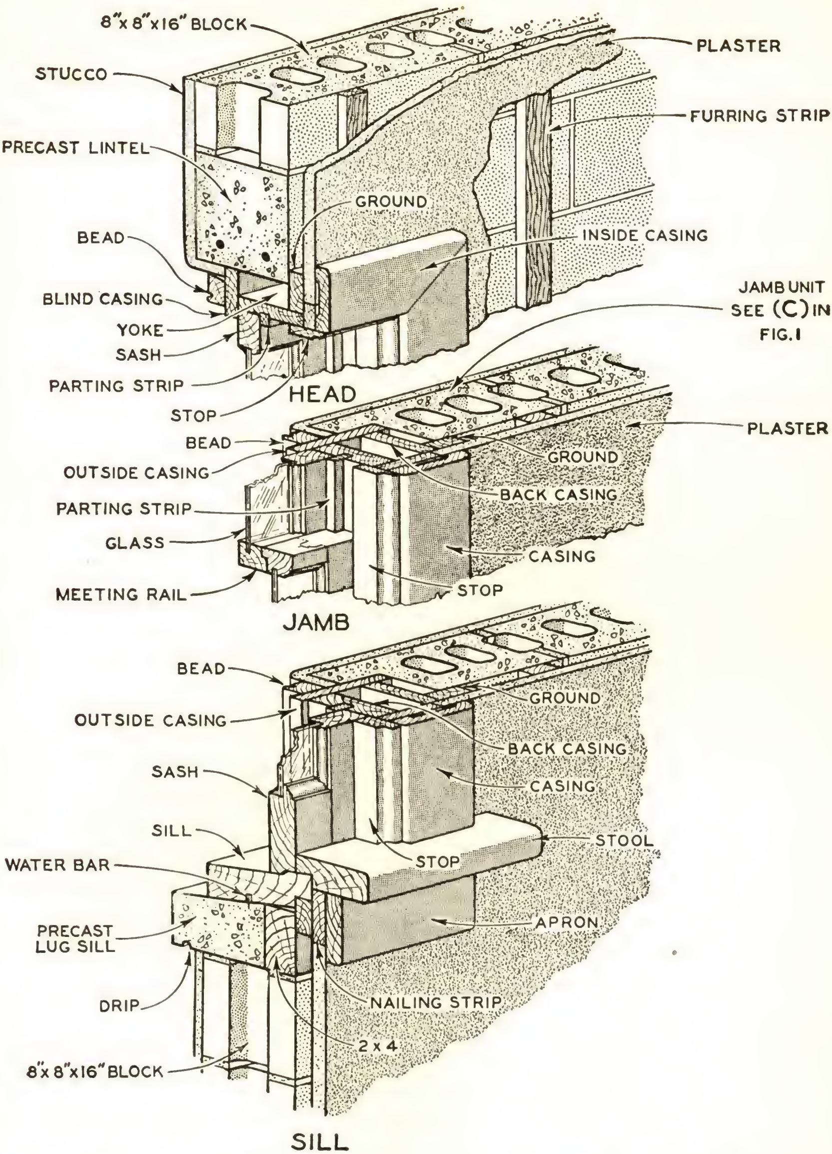


Fig. 13A. Double-Hung Wood Sash Windows in Concrete Masonry Walls
Courtesy of Portland Cement Association

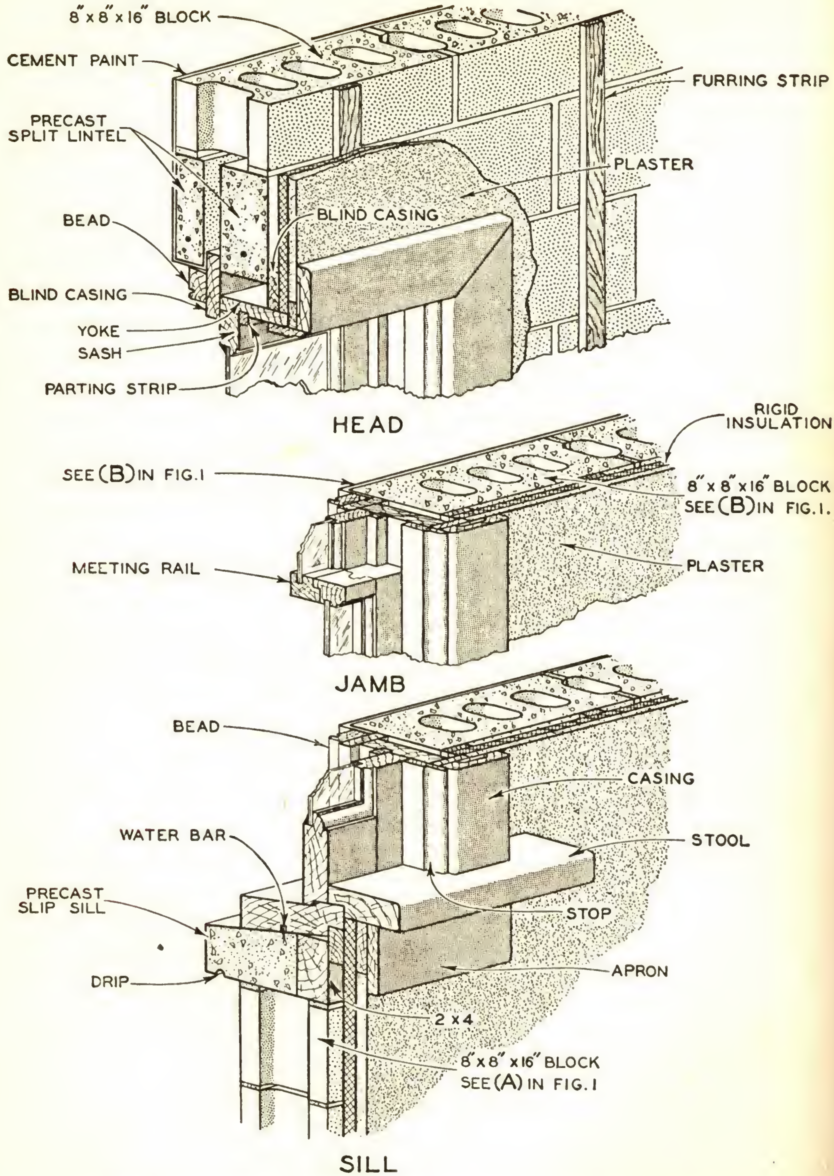


Fig. 13B. Double-Hung Wood Sash Windows in Concrete Masonry Walls

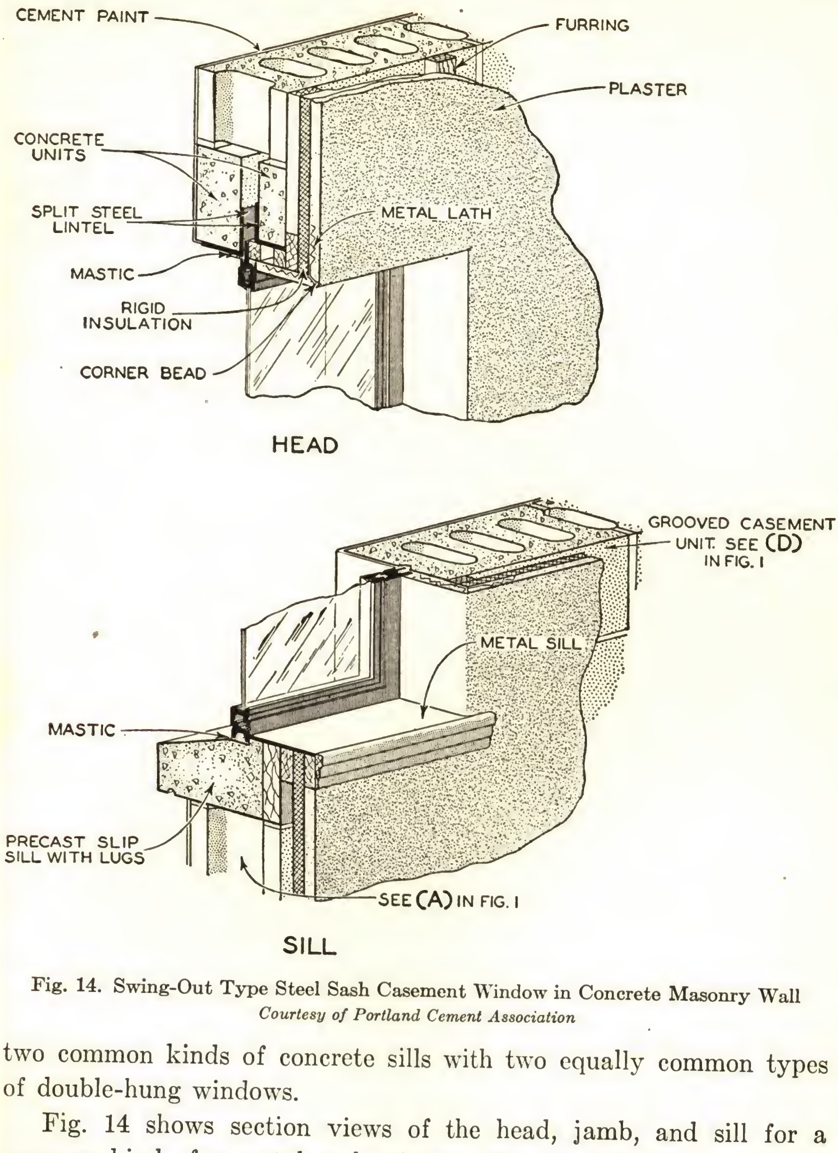


Fig. 14. Swing-Out Type Steel Sash Casement Window in Concrete Masonry Wall
Courtesy of Portland Cement Association

two common kinds of concrete sills with two equally common types of double-hung windows.

Fig. 14 shows section views of the head, jamb, and sill for a common kind of a metal sash window. The head section consists of steel (angle) lintels used in conjunction with precast concrete units plus nailing strips, the metal sash fittings, etc. The jamb section consists of a metal sash block, see (D) in Fig. 1, plus the metal

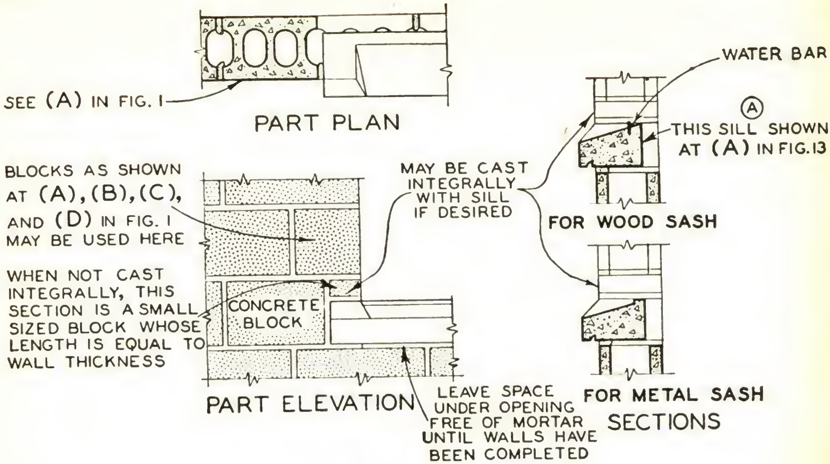


Fig. 15. Lug Sill Details

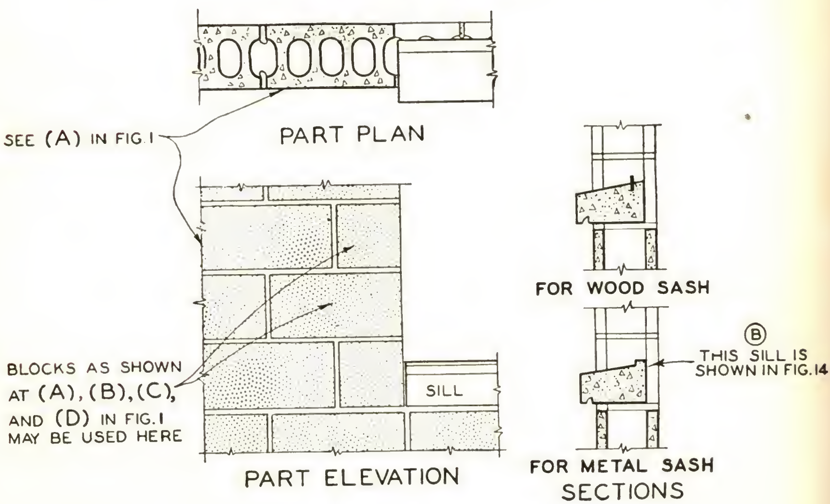


Fig. 16. Slip Sill Details

sash fittings, nailing strip, and plaster. The sill section consists of a concrete slip sill plus the metal sash fittings, metal sill, and nailing strips. The metal fittings are anchored to the concrete sill by bolts set into the sill.

Fig. 15 illustrates plan, elevation, and section views of typical, precast concrete lug sills for wood and steel sash windows. Note that

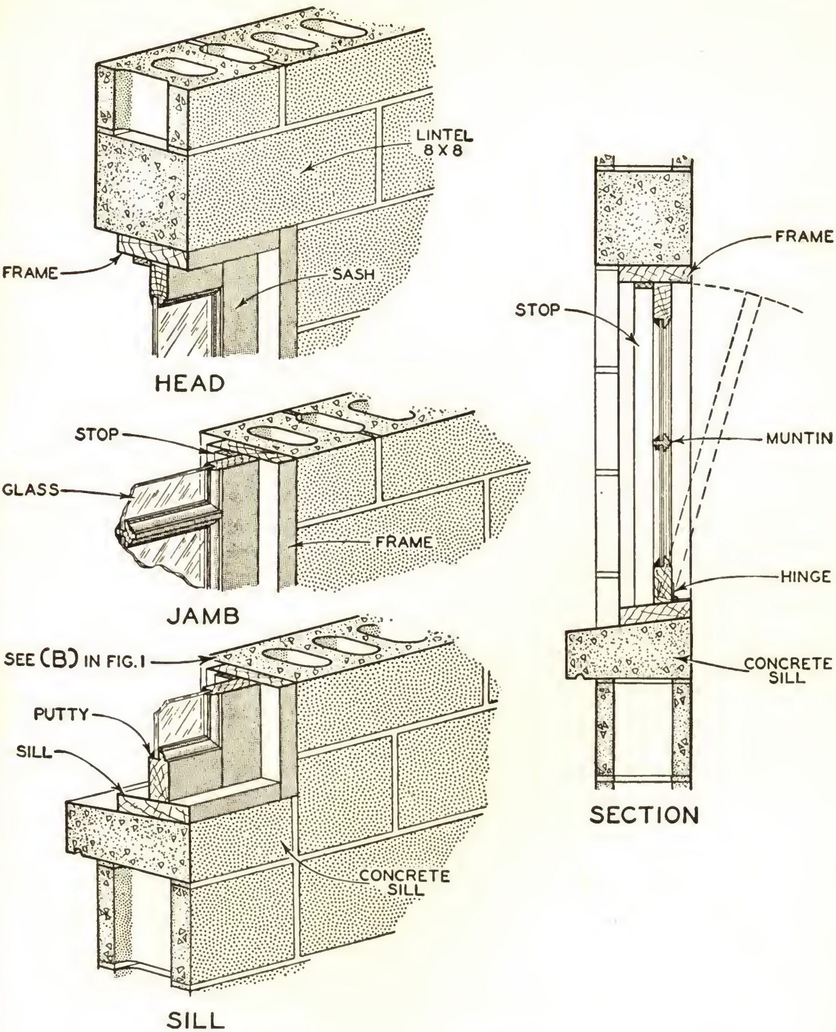


Fig. 17. Typical Details for a Simple Window in a Concrete Block Wall

the lug sill shown in the sill at (A) in Fig. 13 is the same as shown at *A* in Fig. 15.

Fig. 16 illustrates plan, elevation, and section views of typical, precast concrete slip sills for wood and steel sash windows. Note that the slip sill shown in Fig. 14 is the same as shown at *B* in Fig. 16.

Being precast, both lug and slip sills can be placed in the walls when the blocks have been laid up to their level. A study of Figs. 15 and 16 together with Figs. 13 and 14 will provide a knowledge of these common types of sills and their places in concrete walls.

The details presented in the foregoing have to do with the kind

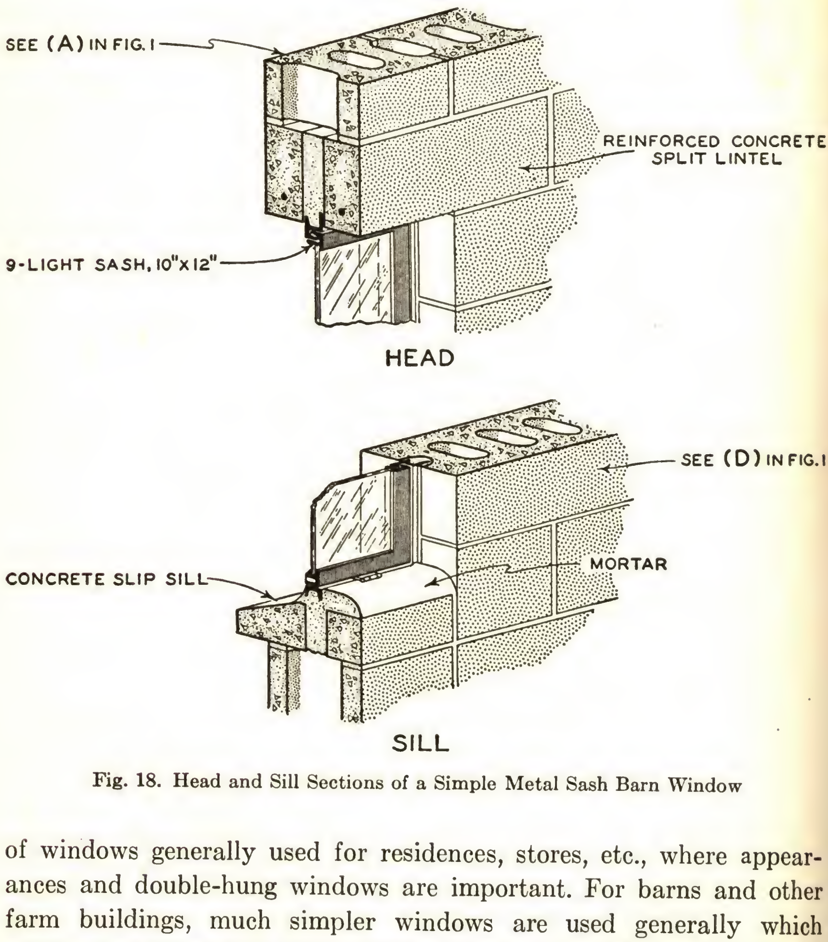


Fig. 18. Head and Sill Sections of a Simple Metal Sash Barn Window

of windows generally used for residences, stores, etc., where appearances and double-hung windows are important. For barns and other farm buildings, much simpler windows are used generally which require less labor and allow simpler construction. Fig. 17 shows the head, jamb, sill, and general section views of a wood-sash window for a typical barn or other small building. Note that the frames are placed next to the lintel, corner return blocks, and sill. The jamb frames

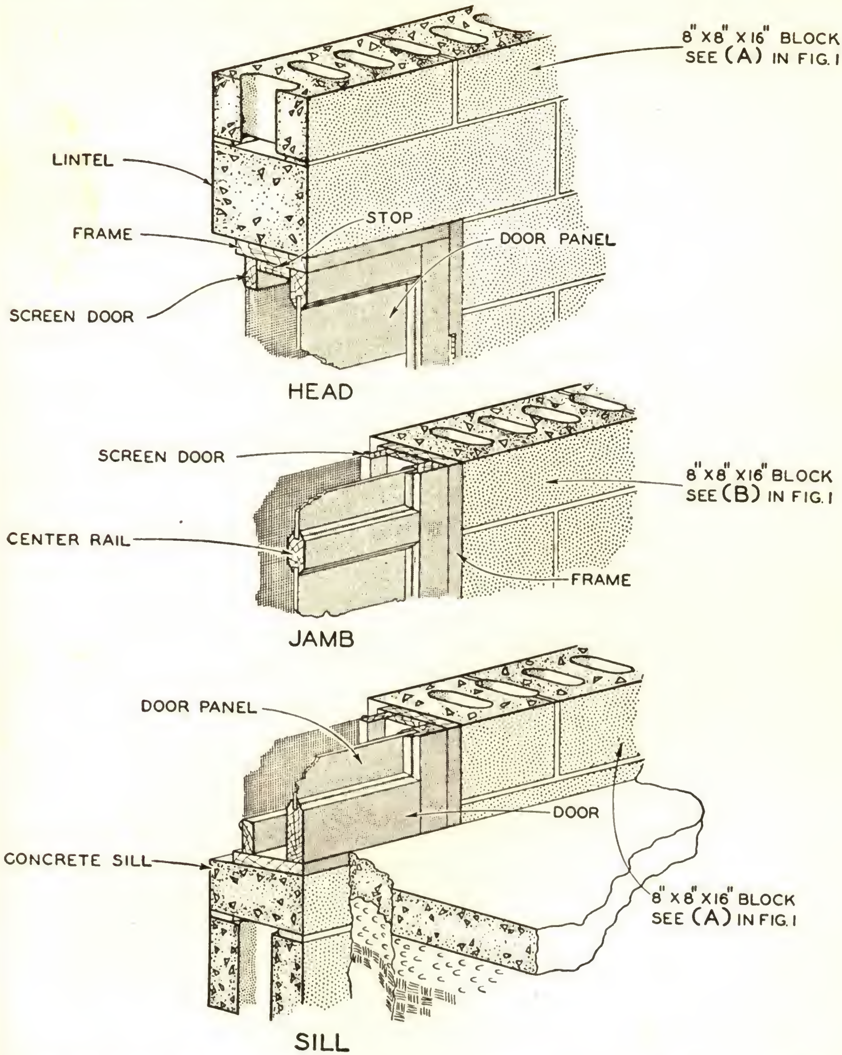


Fig. 19. Head, Jamb, and Sill Sections of Door and Screen Door for Farm Building

are attached to the jamb blocks by nails which are driven into small slats set in the mortar joints.

Fig. 18 shows the head, jamb, and sill sections of a simple metal sash barn window. Note that a split lintel is shown in the head section to provide a means of securing the sash fittings.

Door Details. For the most part, door details are greatly similar to window details as far as concrete block walls are concerned. In most cases, the mason is guided by the doors and frames purchased for each job in that the type of frame determines the type of lintels and jamb blocks to use.

For barns and other farm structures, doors having simple details can be used to advantage. Fig. 19 shows the head, jamb, and sill sections for a door and screen door which can be used for milkhouses and other farm buildings. In the head section, the frame is directly against the under side of the lintel and is held in that position by the side or jamb frames. In the jamb section, the frame is held in place by nails driven through it and into slats set in the mortar joints between the jamb blocks. A precast concrete sill can be used without any form of wood sill. Such frames can be made easily on the job using 2 x 6 planks and 1 x 4 pieces for stops.

Fig. 4 shows the head, jamb, and sill sections for a typical garage door in a concrete block wall. The jamb frames are held in place by bolts imbedded in the mortar joints between the jamb blocks. This manner of securing the jamb frames is advisable because of the size and weight of the doors.

Joist Support. Joists usually support a rather heavy floor load and careful provisions must be made to support their ends in the concrete block walls. There are several ways in which such support may be secured. Fig. 20 shows several typical methods, all of which are acceptable.

Example (A) in Fig. 20 illustrates one of the simplest methods. Here the ends of regular stretcher blocks are cut to allow room for the joist ends. All joists must be beveled as shown at (E). In the event of a fire or accident which results in a collapse of the floor, beveled joists will fall free from their positions in the wall. Joists with square ends will act as levers, prying their way free and destroying the wall. The course of blocks directly under the joists should be solid or have all cores filled with concrete. The bearing of the joists, as shown at (E), should be 4 inches.

In (B) of Fig. 20 is shown the use of special blocks in the course, flush with the joists. All other conditions explained for (A) apply here, too.

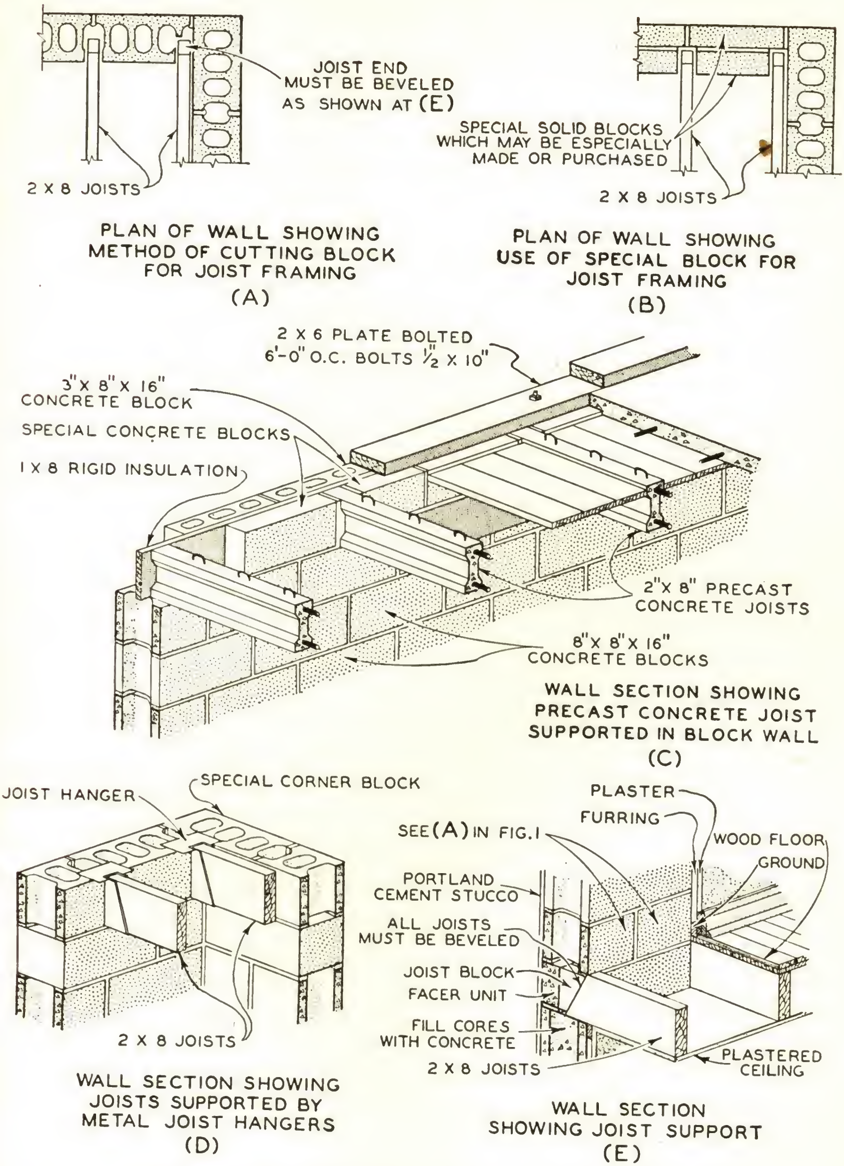


Fig. 20. Details of Joist Bearing in Concrete Masonry Walls

At (C) in Fig. 20, the method of supporting precast concrete joists in a block wall is illustrated. Note that special size blocks are required.

In (D) of Fig. 20, the use of metal joist hangers is illustrated. Here the joists need not be beveled. The hangers, of which several kinds are available, are set into the blocks at their vertical joints.

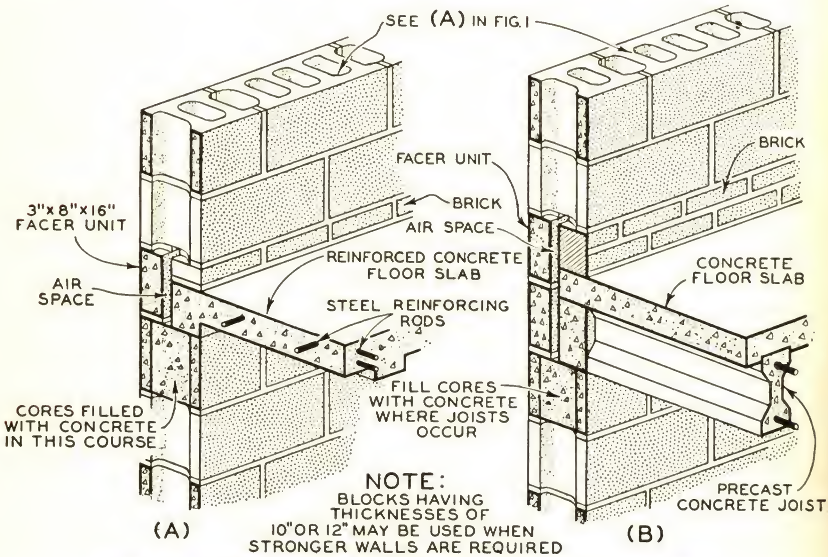


Fig. 21. Details of Support for Concrete Floor in Masonry Wall

(E) of Fig. 20 is a more complicated method of support, wherein special joist blocks and facer units are required. This method is of particular use for residential construction.

It will be noted from a study of Fig. 20, that all joists are 2 x 8 in size. This is necessary to avoid intricate and costly block construction. Where 2 x 10 joists are absolutely necessary, special blocks, as shown at (B) in Fig. 21, are required.

Concrete Floor Support. In buildings such as hay barns where fireproof construction is mandatory, reinforced concrete floors are necessary. Fig. 21 shows two typical methods of supporting such floors in block walls.

In (A) of Fig. 21, where the floor thickness is not equal to 8″, facer units and concrete bricks can be used together with the thick-

ened edge of the concrete floor to build up the wall while providing support for the floor. In (B) of Fig. 21, a more complicated method is required because the thickness of the precast concrete joists plus a concrete floor amounts to more than 8 inches.

Note in both (A) and (B) that an air space is provided. This space can be filled with insulation to help make the wall more resistant to the passage of heat at the points where there are no cores.

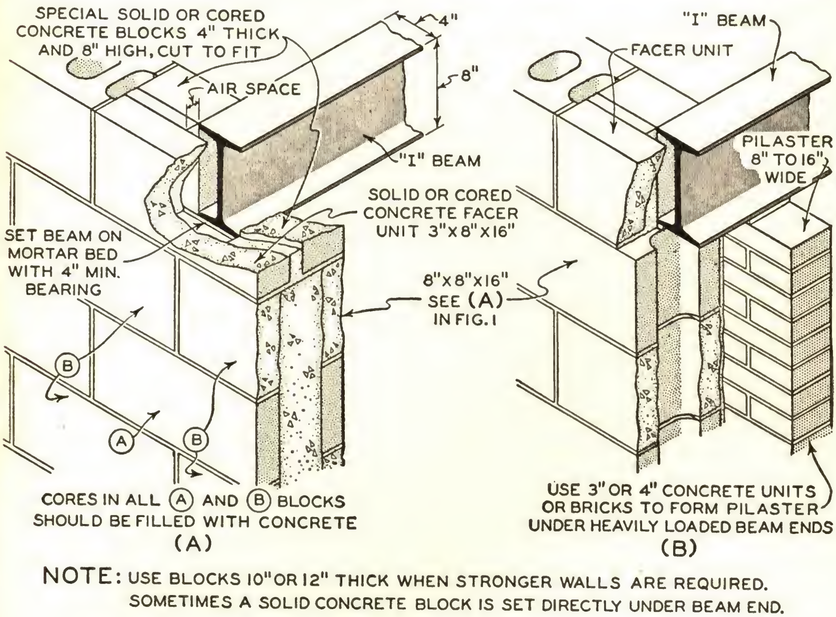


Fig. 22. Typical Method of Supporting Beams in Concrete Block Walls

The most important features to keep in mind with regard to joist and floor supports are that at least 4″ of bearing are required and that the walls must be built up, as shown in Figs. 20 and 21, so as not to impair their strength or stability.

Beam Supports. In most residences, dairy barns, and other larger buildings, there are one or more beams which have to be supported at one end by the walls or foundations. Such beams generally carry heavy loads and therefore must be carefully supported.

In (A) of Fig. 22 is shown a typical case where a block wall supports one end of a beam. The beam should have at least 4″ of

bearing. This is important where heavy loads are involved in order to avoid the shearing off of the edges of blocks. All blocks under the beam (see blocks *A* and *B* in the elevation view) should have their cores filled with concrete. This practice strengthens each block and makes a practically solid concrete column which is capable of supporting great loads.

The top view of the section at (A) shows how facer units and special solid or cored blocks are filled in around the beam to make the wall solid. The special blocks should be placed snugly against the beam web to hold the beam firmly in place.

Sometimes beams carry such heavy loads that the 8″ block wall is not sufficiently strong by itself to safely support the beam ends. In such cases, larger blocks can be used. Should this be inadequate, the wall or foundation can be given considerable added strength by pilasters, as shown in (A) and (B) of Fig. 36. Such pilasters usually are constructed of concrete blocks but bricks or small concrete units also may be used. The pilasters need not be more than 12″ to 24″ wide and should extend from the beam down to the footing or other firm support.

Pilasters and Columns. Sometimes the loads on beams are so great that a large bearing surface and pilaster are required. In such cases, pilasters, as shown at (A) in Fig. 23, are necessary. Such pilasters can be made of standard stretchers and corner blocks as part of regular walls. All cores in the pilaster blocks *A, B,* and *C* should be filled with concrete.

In (B) of Fig. 36 is shown a corner pilaster of the kind used to give stability to block walls.

Columns built of concrete blocks can be made using two or three blocks in each course, as shown at (A) and (B) in Fig. 36. In some parts of the country, circular blocks having a 12″ diameter can be purchased to use in column building.

Concrete Block Wall Intersections. One method of building the intersection when two concrete walls meet at right angles is as shown in Fig. 23. This method does not change the exterior appearance of the wall because block *B* has the same face dimensions as block *A*. The alternate courses shown indicate the method of obtaining a good bond at the intersection.

Chimney Details. The sketches shown in (A), (B), and (C) of Fig. 35 illustrate the use of typical chimney blocks.

Duct Details. The ducts used in connection with heating and air-conditioning systems for residences, stores, etc., are generally from 3½″ to 3⅝″ thick. They can be built in easily to block walls as indicated in Fig. 24.

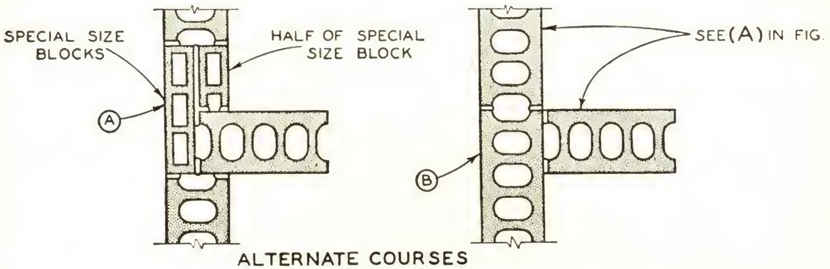


Fig. 23. Method of Joining Concrete Masonry Walls

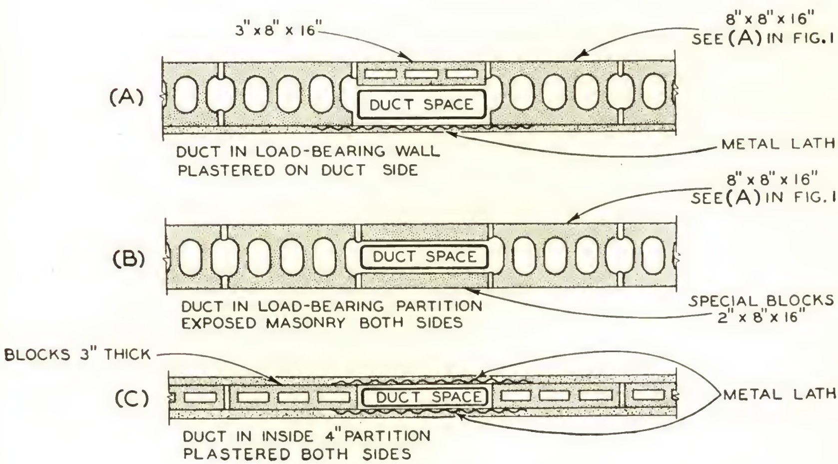


Fig. 24. Duct Details

Nailing Strips. As in all types of masonry walls and partitions, provisions must be made in block walls and partitions for nailing window and door members, baseboards, etc., to them. For example, the jamb frames shown in Figs. 17 and 19 must be secured to the jamb blocks by nailing. As previously mentioned, this is accomplished by

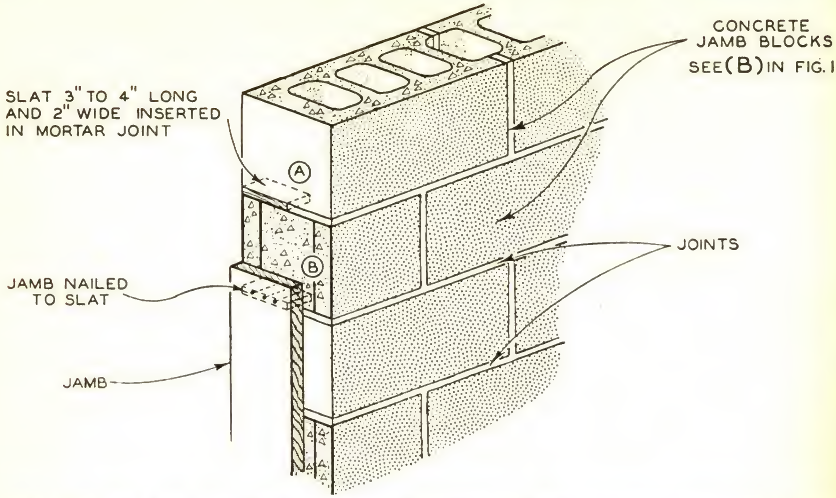


Fig. 25. Slats May Be Inserted into Mortar Joints to Provide Nailing Strips for Jambs

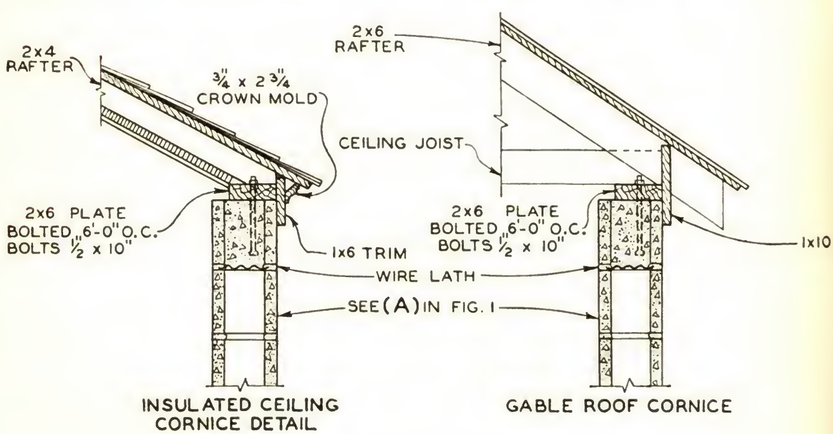


Fig. 26. Cornice Details in Concrete Block Walls

inserting slats in the mortar joints. Fig. 25 shows a typical method. The slats can be put into every or alternate joints. The frames are then nailed tightly to the slats. In like manner, slats can be inserted in joints back of baseboards or any other member which must be nailed as a means of holding it firmly in position.

Cornice Details. Fig. 26 illustrates cornice details for two types of roof. Note that in both cases the top blocks have their cores filled

with concrete. This practice tends to distribute better the weight coming from rafters and ceiling joists. Some masons make it a practice to fill only those cores where the anchor bolts occur. Either method is acceptable.

The cores are filled by laying wire or metal lath under the top-course blocks as indicated. This serves to keep the concrete in place while it is drying. If metal lath is not obtainable, wads of paper can be shoved down into the cores below the top-course blocks to keep the wet concrete in place.

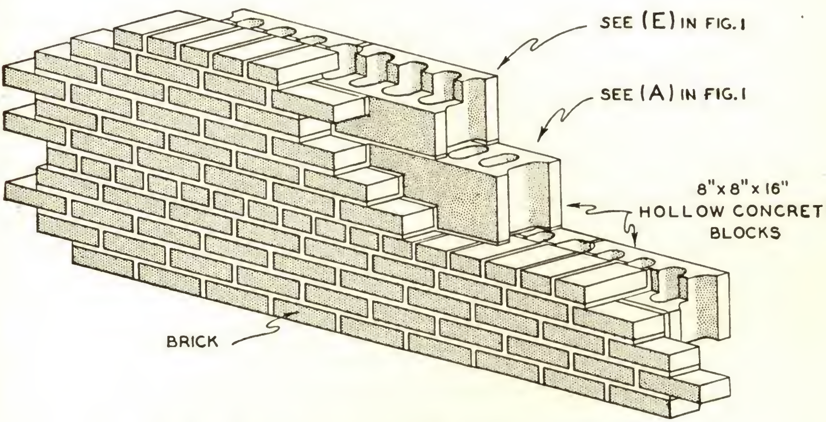


Fig. 27. Veneer Wall Having Concrete Block Backing

Veneer Details. Fig. 27 illustrates the method of using concrete blocks as backing for brick veneer in a wall. Note that the block is the same as shown at (E) in Fig. 1.

Typical Wall Section. The typical wall section shown in Fig. 28 illustrates a good many of the details already discussed. Some of these details are a little different but their use and positions are the same. This illustration serves the purpose of helping the reader to visualize better, typical concrete block wall details.

The lintels shown at *A* are of a variety not previously explained. However, it can be seen easily that their shape is designed to accommodate the particular head section of the windows in a different manner than shown in Fig. 13.

It will be noticed that the section indicates stucco outside surfacing

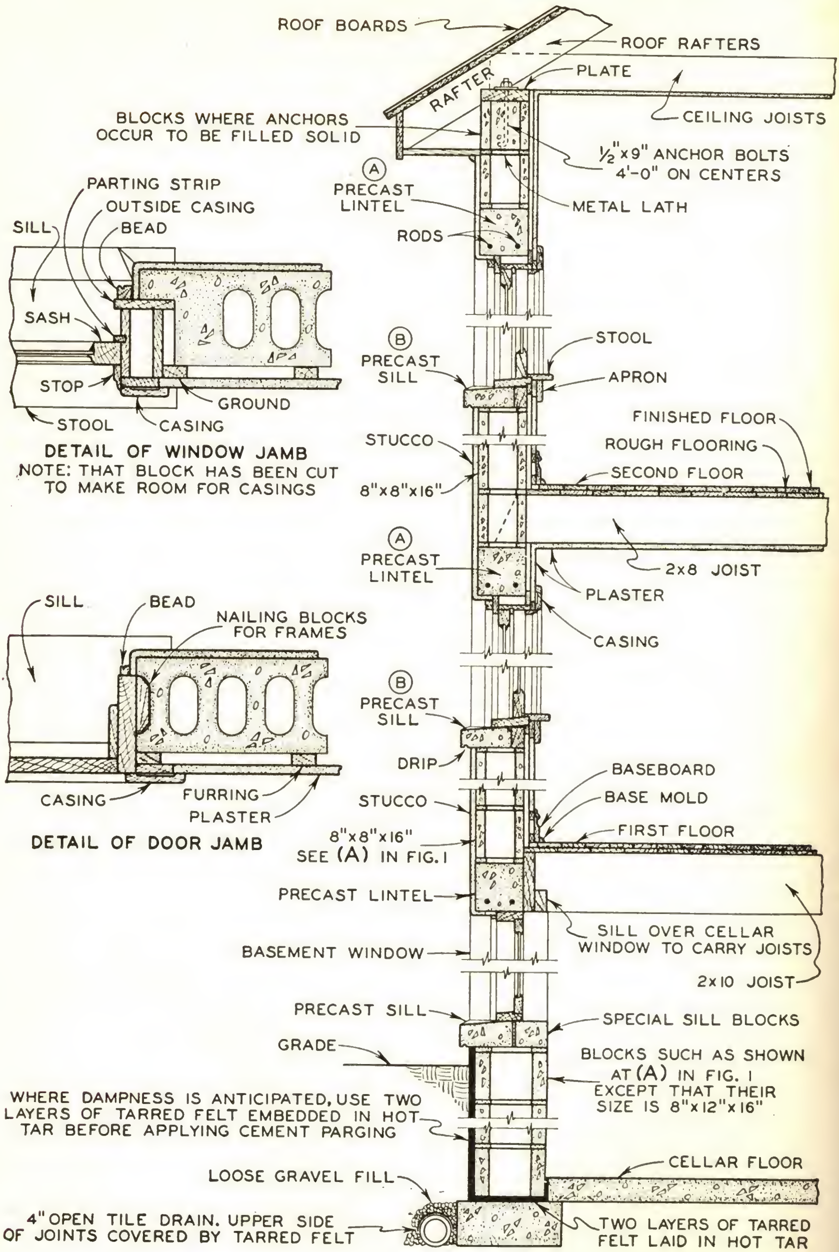


Fig. 28. Typical Details of a Concrete Masonry Wall

and that the interior wall surfaces are furred and plastered. The foundation portion of the section shows the use of blocks which are 12″ thick. A special type sill block is used in connection with the basement window because of the 12″ foundation blocks. An acceptable method of supporting 2 x 10 joists over the basement window also is indicated. The window and door jamb details are little different from those previously discussed.

LAYING CONCRETE BLOCKS

When the commonly used kinds of concrete block are known, when the uses of such blocks in connection with concrete masonry are also known, and when typical construction details are understood and can be visualized, the next logical step is to learn how this kind of masonry is actually laid. The processes or techniques involved are not difficult and the aim of the following explanations is to describe and illustrate several typical examples of concrete masonry. The examples set forth are simple, but they represent the kind of jobs most frequently required.

Laying Concrete Block Walls. For this example the milkhouse drawings shown in Fig. 3 will be used.

From a study of these drawings, it can be seen that the walls are to be constructed of concrete blocks such as shown at (A) and (B) in Fig. 1. It can be seen also that the over-all dimensions of the milkhouse are 13′ 6″ x 12′ 0″, that 1′ 4″ x 8″ concrete footings are required, and that the concrete blocks are to start right above the footings.

It is assumed that a trench of ample size was excavated in order to place the footings and that this trench has been left open for the laying of the concrete blocks.

The cross section drawing of the footings shown in the section drawing indicate that the blocks are to be set directly in the middle of the footing. Or, the blocks are to be set 4″ back from the edge of the footing. Refer to Fig. 29. In this illustration, the dotted lines indicate the edges of the footings. It will be noted that only wall *AB* (see plan in Fig. 3) is shown in Fig. 29 as this wall is sufficient for explanatory purposes.

Inexperienced masons can draw chalk lines on the footing to indicate the exact position of the first course of blocks. In Fig. 29 such lines are shown from *A* to *B*, from *B* to *C*, and from *A* to *D*.

The first step in laying concrete block walls is to set blocks without

mortar all around the footing for the purpose of checking the designer's dimensions. It is assumed that the designer considered block lengths plus vertical mortar joints when the 13′ 6″ and 12′ 0″ wall lengths were decided upon. Place corner return blocks, as shown at *X* and *Y* in Fig. 29, up to the chalk lines. Then place the regular stretcher blocks, numbered 1 through 9, assuming that the joints will be each somewhat over ¼″ thick. In this case, 9 blocks fit easily between blocks *X* and *Y* with some additional space. The exact space to allow for each joint can be calculated easily as follows:

The 13′ 6″ dimension equals 162 inches. Deducting 16″ (combined width of blocks *X* and *Y*) leaves a total of 146″ which is taken up by 9

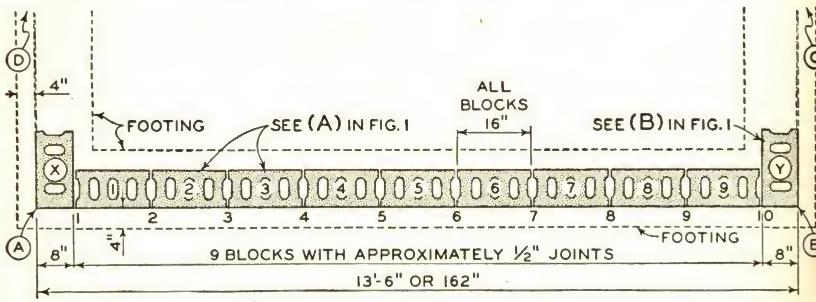


Fig. 29. Layout of Blocks along Side *AB* of Milkhouse Shown in the Plan View of Fig. 3A

blocks and 10 joints as shown in Fig. 29. Each block is actually 15¾″ long, then nine blocks make a total of 15¾″ multiplied by 9, or 141¼ inches. Subtracting 141¼″ from 146″ leaves 4¾ inches. For ease in calculation call this an even 5 inches. There are to be 10 joints so 5 divided by 10 equals .5 or ½ inch. Thus, each vertical joint must be about ½ inch. This is larger than the recommended ¼″ to ⅜″ vertical joints but cannot be changed at this stage. In the case of the milkhouse, there are two 13′ 6″ walls and two 12′ 0″ walls. Therefore, it is only necessary to place the blocks along one of the 13′ 6″ and one of the 12′ 0″ sides to check as previously explained. The blocks can be placed along wall *BC* or *AD* as described for wall *AB*.

Before the second step in laying a concrete block wall is started, it is necessary to determine what size horizontal mortar joints must be used. The section drawing in Fig. 3 shows that the total height of the concrete block wall from the footings to the top course is 10′ 4 inches. The height of the blocks is 7¾ inches. Changing 10′ 4″ to inches makes

124 inches. The section view shows that 15 courses and 15 joints are necessary in the walls. Multiplying 15 by 7¾″ gives approximately 116 inches. Subtracting 116″ from 124″ leaves 8 inches. To find the horizontal joint thickness divide 8 by 15 which indicates that each joint must be slightly more than ½ inch. One, two, or three of the horizontal joints can be made enough larger than ½″ to make up the required difference.

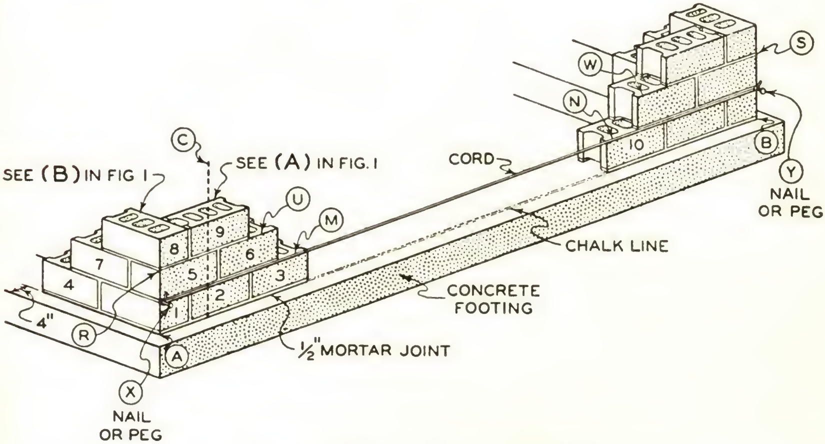


Fig. 30. Second Step in Laying a Concrete Block Wall

The second step in laying a concrete block wall is illustrated in Fig. 30 and consists of laying about three courses of blocks at two corners along the same wall, it being understood that proper mortar, previously described, is ready for use and that the blocks are perfectly dry. The use of blocks which have been wet is not recommended.

To lay block No. 1 shown in Fig. 30, first apply mortar to the footing, as shown at (A) in Fig. 31. The rows should be about 2″ wide, and 1″ to 1½″ deep. Rows *A* and *B* should be slightly longer than a block. Rows *A* and *C* should be next to the chalk line.

Lay the block carefully on the mortar, as shown at (B) in Fig. 31, and make sure that its faces *D* and *E* are directly over the chalk line. The block can be pushed downward by hand, by the trowel handle, or by using a hammer handle until the joint between it and the footing is ½ inch. The excess mortar can be removed using the trowel, taking care not to remove mortar beyond the point of its being flush with the side

of the block. Then place the plumb rule (level) in the positions shown by dotted lines *X* and *Y* in order to check the block's position. If it is out of plumb in either direction, the necessary corrections can be made by pushing downward or, if necessary, by picking up the block and adding more mortar after which the same procedure as previously explained must be followed. Every block laid must be absolutely plumb in both directions.

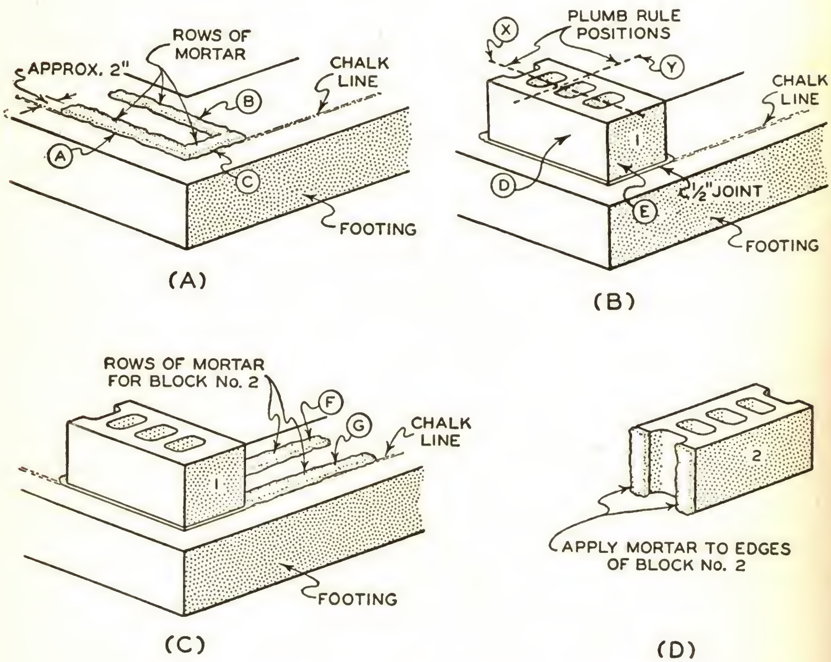


Fig. 31. Spreading the Mortar Bed and Placing the Corner Block

The amount of mortar to use will be learned by experience.

When block *1* is plumb and the joint is smooth and flush with the faces, block *2* in Fig. 30 can be laid. First apply two rows of mortar, as shown by *F* and *G* at (C) in Fig. 31. These rows are applied just as for block *1*. The two edges of block *2* should have mortar applied to them about an inch thick, as shown at (D) in Fig. 31. Then place the block into position, shoving it carefully to make the required vertical and horizontal joints. Care must be taken not to displace block *1*.

Block *2* is pushed downward for proper alignment in the same manner explained for block *1*. Use the plumb rule to check position and remove excess mortar by running the edge of the trowel along the joint.

Place blocks *3* and *4* in Fig. 32 in the same manner explained for block 2.

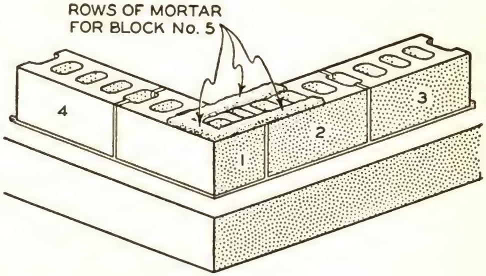


Fig. 32. Spreading the Mortar Bed for the Second or Alternate Course

To lay block *5* in Fig. 30, place the rows of mortar as shown in Fig. 32. Then lift the block and lay it carefully into place over blocks *1* and *2*. It is pressed down, checked by the plumb rule, and the joints smoothed. Care should be taken not to misplace the previously laid blocks and to see that the outside faces of block *5* are flush with the faces of the blocks below it. This can be checked by holding the plumb rule against the blocks as indicated by dotted line *C* in Fig. 30. Both faces must be checked and the block moved one way or the other, if it is not exactly in line with the blocks below.

Blocks *6, 7, 8,* and *9* are laid following the same procedures given for the first five blocks, taking special care with the joints in order that each block is plumb and that the face or faces of each block laid is or are directly in line with the blocks below. The face of the wall must be absolutely vertical. The blocks forming the other corner shown in Fig. 30 should be laid in the same manner.

When both corners have been laid, as shown in Fig. 30, drive nails gently into the mortar joints at *X* and *Y,* then stretch a cord, also indicated in Fig. 30, between the nails (and tied to them) so that it just touches the edges of the blocks *M* and *N*. This cord should be tight.

The first course blocks between blocks *3* and *10* can now be laid, making sure that the edge of each just touches the cord. When laying these blocks, apply the mortar, press them into place, use the plumb rule, and smooth the joints as previously explained.

When the first course is laid, move the nails to *R* and *S,* as shown in Fig. 30, and stretch the cord so it just touches the edges *U* and *W* of the second course blocks. Then complete the second course.

Next lay the blocks forming another corner at *D* (see Fig. 3) and lay the intervening blocks for wall *AD* as explained for wall *AB*. Finally lay the blocks for the corner at *C* and then lay the intervening blocks forming walls *DC* and *CB*. This kind of masonry work should not be done during freezing weather.

When all walls have been built up two courses, start again at the corners *A* and *B* and lay 9 more blocks at each corner. Then stretch the cord and proceed as before. Lay two more courses in all four walls. This process is continued, except around windows and doors, until the walls have been built up to the required height.

Where cores must be filled with concrete, a 1: 2:4 mix may be used. Place the concrete carefully to make sure that the cores are completely filled. This can be assured by tamping lightly. Smooth the tops of each filled core with a trowel and make each fill level with the webs and face shells of the block. When anchors are required, they should be held in position and the concrete poured around them. All anchors must stand absolutely vertical in the concrete and extend above it just enough to accommodate the wood plates, the washer, and the nut.

Laying Concrete Block Partitions. The procedure for laying partition blocks is practically the same as explained for walls in that the corners or ends should be laid up for a few courses and then the intervening blocks laid, etc.

Bearing partitions, those which must support ends of floor joists, should have two or three courses of brick laid at their tops as a means of better distributing the weight from the joists. If for any reason it is not desirable to top off such partitions with brick courses, the cores of the top course of blocks can be filled with concrete.

No matter which of the foregoing methods is followed, it is advisable to use a 2 x 4, 2 x 6, or 2 x 8 plate on top of the partition as a bearing surface and nailing strip for the joists.

Nonbearing partitions or those which support only their own weight as (C) in Fig. 26, can be topped off by a final course of whatever kind of block is being used.

Laying Concrete Blocks around Windows. In wall AB, shown in the plan and pictorial views of Fig. 3, a window is indicated, the details for which are given in Fig. 17. Fig. 33 shows the frame for this window in the partly laid block wall. The purpose of this illustration is to show

the positions of the frame for sill, jamb, and head in a wall. The procedure for setting the frame in place and laying the blocks around it is as follows:

You must first determine from the plans such as the section drawing in Fig. 3, the position of the window in terms of the number of courses under the sill and the number of blocks on either side of it. Then the wall should be laid up to and including the course under the sill. Thus wall *AB* would be laid up to and including the course marked *A* in Fig. 33.

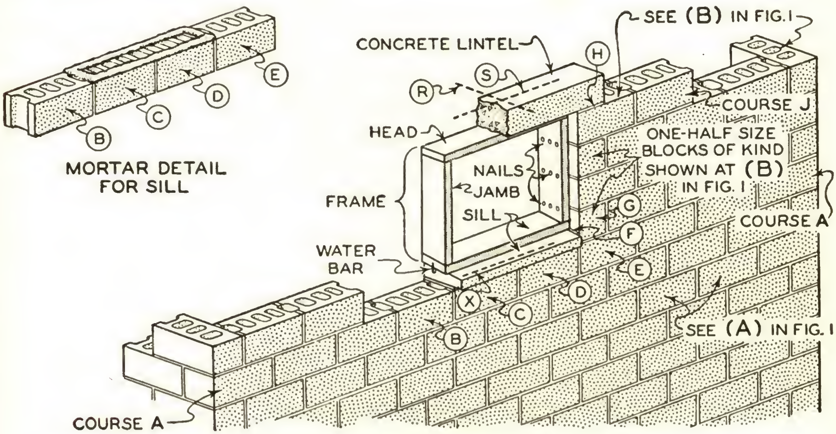


Fig. 33. Part of One-Room Milkhouse Wall Showing Window, Sill, and Lintel

Next apply mortar to the blocks which will be directly under the sill. In Fig. 33, these blocks are shown as *C* and *D* and the method of mortar application is shown in the mortar detail for the sill. The width and depth of the mortar should be the same as previously described. Then set the sill gently in place and press it down until the mortar joint is the same as for the other horizontal joints. Remove excess mortar and smooth the joint surfaces on both sides of the wall. Check the level of the sill by placing the plumb rule on the sill in the position of the dotted line, *X*. If the sill is not level, press or force it downward at either end as required. If leveling cannot be accomplished in this manner, remove the sill, apply more mortar, and try resetting.

When the sill has been properly laid and checked, the next step is to place the window frame on the sill. The frame can be held in place

by pieces of 1 x 2 or 1 x 4 or by any other available wood pieces lightly nailed to the frame at one of their ends and supported or held in place at their other ends by flooring, stakes, etc. Carpenters generally put such frames in place for the masons. In any event, the frames must stand vertically plumb and square with the wall.

The sill shown in Fig. 33 is a slip sill. When lug sills are laid, mortar should be applied near the ends of the sills only, until such time as the wall has been completed. Then mortar can be forced under the sill and the joint completed. When lug sills are used, the window frames are generally placed and held in proper position before the sill is laid.

Many masons prefer to lay the blocks around window frames following the method outlined in laying a block wall. In other words, after the sill is laid, they stretch the cord for each course and lay the blocks course by course, including those around the frames. This is perhaps the best method for inexperienced masons because it assures all courses being laid in proper alignment. Some masons prefer to lay blocks around window frames well ahead of the other courses in much the same manner as for corners. Whichever method is followed, special care must be taken to keep all blocks exactly one above the other in order to insure a vertical wall.

Note the joint *F* between the sill and the jamb block *G* in Fig. 33. Before block *G* is laid, the end of the sill should have mortar applied to it so that joint *F* contains mortar and is the same thickness as other vertical joints.

When the blocks around the window frame have been laid, including the course at *J* on both sides of the frame, the concrete lintel can be placed. If the window opening is wide and the lintel, therefore, long and heavy, some time should be allowed for the mortar in the courses below to harden before the lintel is set.

To set the lintel, apply mortar to the blocks (see *H*) on either side of the frame. Then set the lintel gently down into proper position and adjust until the mortar joint is the same thickness as other horizontal joints. Special care should be taken to see that the lintel is perfectly level. This can be accomplished by setting the plumb rule in the positions of dotted lines *R* and *S*. Above the lintel, the blocks are laid as in the balance of the wall. Mortar for the blocks directly above the lintel is applied to the lintel in the usual manner.

Nailing strips, not quite as long as the jamb frame is wide, can be inserted in the jamb block joints as the jamb blocks are laid.

When concrete blocks are to be supported by steel lintels, as shown in Fig. 14, some mortar should be applied to both the horizontal and vertical sides of the lintels and the blocks laid on the mortar.

Laying Blocks around Door Openings. In wall *AD* shown in the plan and the pictorial views of Fig. 3, a door, the details for which are given in Fig. 19, is indicated. Fig. 34 shows the frame for that door

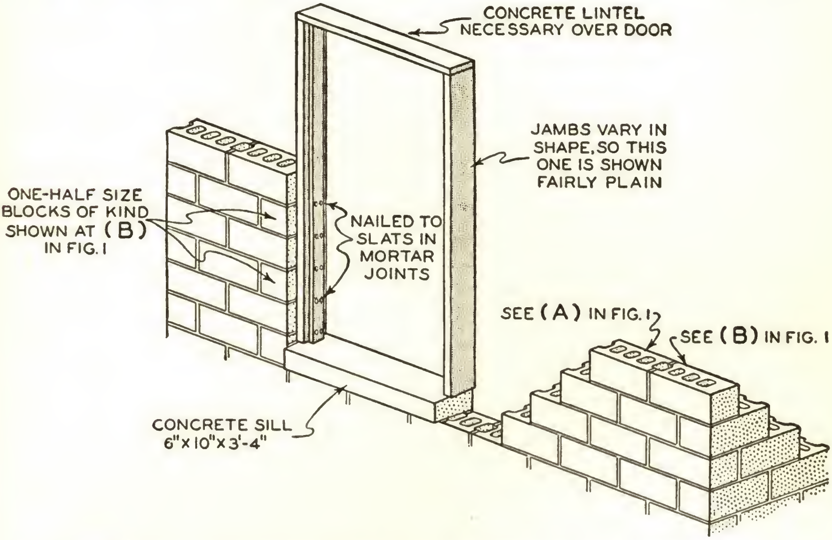


Fig. 34. Part of One-Room Milkhouse Wall Showing Door Frame in Place

in the partly laid block wall. The purpose of this illustration is to show the positions of the frame for the jamb and head in a wall. The procedure for laying blocks around door frames is the same as that given for windows.

Laying Concrete Block Chimneys. When chimney blocks of the general kind shown at (A) in Fig. 35 are laid, the procedure is as follows:

First mark with chalk the exact position for the first course on the footing. The position can be ascertained from the blueprints of the building the chimney is to be in.

Apply mortar to the footing so that it will be under the areas marked

X in Fig. 35, wide enough to cover the areas and about 1″ deep. Note that this includes the flue lining which is part of each block. Care must be taken to have mortar all the way around under the areas marked X. Place the first block and press it gently down into the mortar to make a joint of the same thickness as used for walls. Then remove excess

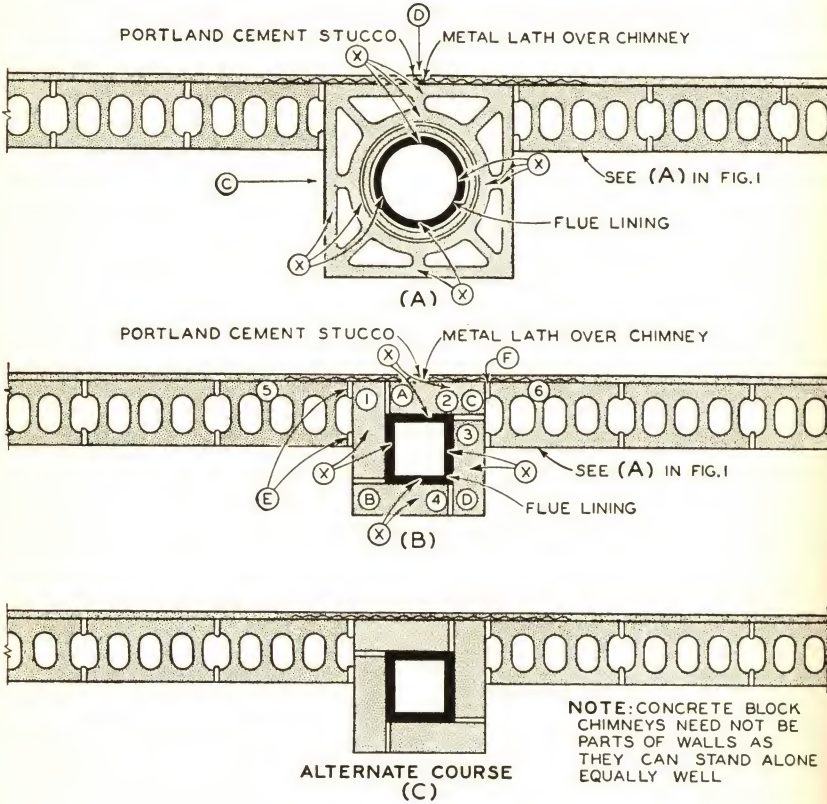


Fig. 35. Chimney Details

mortar. Check the level of this block by placing the plumb rule across the block in the direction of the arrows at C and D. Make any adjustments necessary relative to leveling. This block must be *absolutely* level.

Apply mortar to the first block at all areas marked X all the way around the block. Then place the second block gently in position, press it down to form proper thickness of joint, remove excess mortar and

smooth the joint, and check its level, as for the first block. Also, place the plumb rule in a vertical position, up against the four sides of the chimney to make sure the sides are perfectly in line and vertical. The mortar joint for the flue lining must be smooth and should not protrude between the surface of the lining. Each such joint must be smoothed as each block is laid.

Place succeeding blocks in like manner, being sure to watch every detail explained for the first two blocks.

When chimney blocks of the kind shown at (B) in Fig. 35 are being laid, the procedure is as follows:

The exact position of the chimney should be marked on the footing. Then place mortar so that it is completely under all areas marked *X*. In other words, each block must have a full mortar bedding. Also place mortar at the ends of block 5 at the points marked *E*. Chimney block *1* should then be pressed into position, making sure the joints at *E* and the joint between the block and the footing are of the proper thickness. Make sure that the end of the block lines up with the face of block *5*. Check the level of block *1*. Next apply mortar to block *2* at the end where it touches block *1* (joint *A*) and on block *6* at the point *F*. Press this block into position as for block *1*, making sure it lines up with the face of block *6*. Place blocks *3* and *4* in the same manner, taking care to make joints *C, D,* and *B* carefully.

Most masons prefer to set the first length of flue lining in place before more courses of blocks are laid. Blocks *1, 2, 3,* and *4* must fit tightly against the flue lining as shown at (B) in Fig. 35.

For the second course of blocks, apply mortar all around completely covering the first course. For this course, place the blocks as shown at (C). This is necessary to create good bond.

Place succeeding courses alternating them as explained. As each length of flue lining is added, a careful mortar joint must be made between lengths. Special care must be taken that all flue lining joints are smooth on the inside of the flues.

As the chimney construction progresses, frequent checks by the use of the plumb rule should be made to see that the chimney is perfectly vertical. All excess mortar should be removed and the joints smoothed.

Note, in Fig. 35, that metal lath should be applied to the exterior

wall surface at and on either side of the chimney if and before stucco is applied. The stucco can be secured to the wall by the use of nails driven into the blocks if they are the lightweight kind or into the joints if heavyweight blocks are used. The metal lath tends to avoid wall cracks near the chimney at times when the chimney sways slightly due to wind, etc.

Laying Concrete Blocks for Pilasters. The pilasters or columns at (A) and (B) in Fig. 36 are both constructed as integral parts of walls and as the walls are constructed. In (A), block *A* is put into place as part of the wall. Then block *C* is placed and finally block *B*. When blocks *A, C,* and *B* have been laid, the plumb rule should be used in two directions across the pilaster to make sure the whole course is perfectly level.

When the next course of the wall is being laid, apply mortar as shown in (C) of Fig. 36 so that block *C,* as shown in (A), will be on the opposite side. This practice creates good bond. The following course can be as shown in (A), etc. Frequent checks should be made to see that all blocks are level and perfectly vertical. The pilaster shown in (B) of Fig. 36 is laid following the same general procedure.

HOMEMADE CONCRETE BLOCKS

Concrete blocks of practically all sizes and shapes are generally available in most localities and can be purchased ready to use. However, if they cannot be purchased locally they can be made according to the following instructions.

The necessary forms can be purchased ready to use from any one of several manufacturers, the names of whom can be obtained from building material dealers. Or, such forms can be home made from such plans as those shown in Fig. 37. These forms can be made to produce blocks of any desired shape and size.

The mixing of the necessary concrete, its placing in the forms, and curing of the blocks is not difficult and can be done readily by anyone. There is no standard proportion for concrete to be used in concrete blocks. However, for ordinary blocks, a mix of 1:2:4 is satisfactory if Portland cement is used.

For ordinary concrete blocks, the concrete should have enough water added during the mixing to make the concrete plastic in consistency

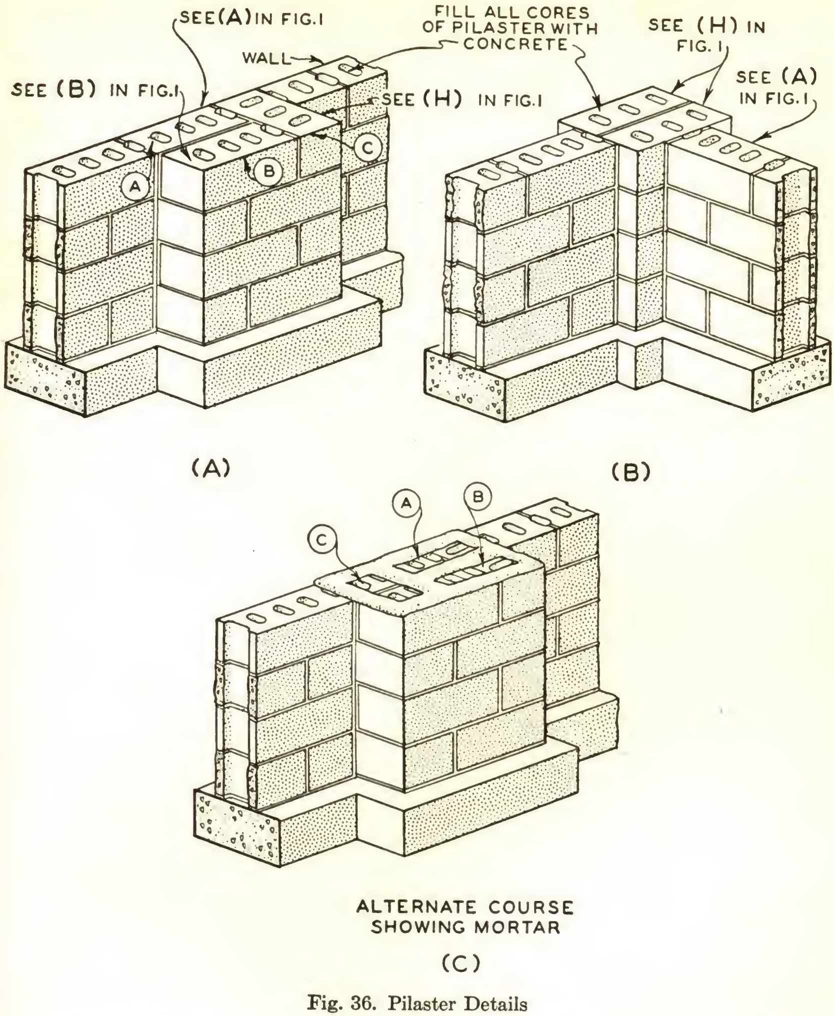


Fig. 36. Pilaster Details

but not wet or watery. For plain finish blocks, the concrete is placed in the forms and carefully spaded to make certain no voids are left in the form. For blocks which must have one smooth face, as for milk-houses, etc., the form should be filled with regular concrete to within ½″ of the top. A mixture of one part cement and one part sand should then be used to fill the balance of the form and should be troweled smooth.

Forms should not be removed for at least 12 hours during warm weather and not sooner than two or three days in cold weather. For forms such as shown in Fig. 37, the cores should be removed by first gently tapping them and then pulling them out slowly. The balance of the form also should be removed carefully to avoid breaking corners or edges of the block.

The newly made blocks should be stored where they are sheltered from wind and sunshine for a period of about 28 days before being used.

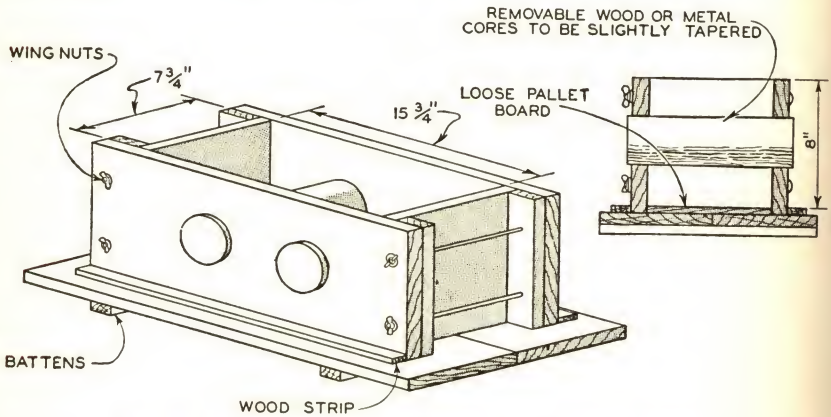


Fig. 37. Homemade Wood Forms for Making Concrete Blocks

PAINTING CONCRETE MASONRY

Mixtures of Portland cement with water as a vehicle to which waterproofing agents, colored mineral oxides, and other ingredients have been added, readily can be used to waterproof concrete block walls as well as to add to their beauty. It is recommended that Portland cement paint ready to use be purchased rather than to attempt to make it on the job. Practically all building material dealers sell such products.

If block walls are to be painted, two coats, called the *seal* and *finish* coats, should be used. Wall surfaces should be dampened just prior to the application of the seal coat. The seal coat should be *scrubbed* into the wall surface as this practice avoids pin holes in the paint. Ordinary scrub brushes with stiff fiber bristles have been found to be the most satisfactory because they force the paint into the pores

of the blocks. Use ample amounts of the paint in the brush and completely cover the wall surfaces, including the joints.

The finish coat can be applied within 48 hours after the seal coat has been put on. Enough paint should be applied over the seal coat to cover it completely. The finish coat should be sprayed on providing ordinary paint spraying equipment is available. When spraying, the nozzle of the spray should be manipulated so that the spray hits every point of the wall surface from four or five angles. If the work must be done by hand, a six-inch brush will be found to be most practical.

Seal and finish coats should be kept in a moist condition for a period of at least 48 hours following application. This can be accomplished by spraying with water at intervals after the paint has set.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. How to find the length of a concrete masonry wall composed of 8″x 8″x 16″ units having ¼″ mortar joints exclusive of end blocks?

Answer. Table I shows that such a wall would be 26′ 8″ long.

2. What kind of 8″x 8″x16″ concrete blocks generally are used around window openings?

Answer. The blocks shown in (B), (C), and (D) of Fig. 1 generally are used around window openings.

3. How a wood jamb is held in place if blocks such as (B) in Fig. 1 were used around window openings?

Answer. The wood jamb is nailed to slats which are inserted into the joints between the jamb blocks as indicated in Fig. 25. If lightweight blocks are used, the wood jambs can be nailed directly to the blocks.

4. How wood jambs for heavy doors such as for garages are secured in place?

Answer. Bolts are embedded in mortar joints between jamb blocks and the wood jambs secured by nuts as shown by the door section in Fig. 4.

5. What type of concrete masonry sill actually extends into the walls?

Answer. The lug type sill.

6. What special processing must be given to the blocks in a wall directly under the point where a beam end is supported by the wall?

Answer. The blocks directly under the beam bearing must have their cores filled with concrete between the beam bearing and the footing. This is well illustrated in Fig. 22.

7. What can be done to strengthen a block wall under a beam bearing area?

Answer. As indicated in Fig. 36, a brick pilaster can be laid up against the wall as a means of providing considerably more strength.

8. Why plain finish concrete blocks are best suited to walls which have a stucco finish?

Answer. Because the irregular finish of such blocks provides a better bond for the stucco.

9. What size joists can be used to the best advantage in connection with block walls?

Answer. Joists which are 2″ x 8″ in size work out to best advantage because blocks are 8″ high.

10. What minimum amount of bearing to allow for beams in block walls?

Answer. At least 4 inches.

11. Where water bars are used and why?

Answer. Water bars are used in sills as a means of preventing water from passing between the wood and concrete sills.

12. Where beads are used and why?

Answer. Beads are used at the heads and jambs of windows as a means of finishing off corners between casings and walls.

13. What a corner bead is and where it is used?

Answer. A corner bead is a metal protector used on all plaster corners.

14. Where grout is used in connection with wood or metal sash windows in block walls?

Answer. Metal sash windows.

15. Where joist blocks are used?

Answer. Between the joists at their bearing ends in concrete block walls.

16. If it is necessary to purchase special flue liners for one-piece chimney blocks?

Answer. The flue lining is built in, so liners are unnecessary.

17. How anchor bolts are secured in concrete block walls?

Answer. By placing them in cores and then filling the cores with concrete.

REVIEW QUESTIONS

1. A concrete masonry wall composed of units 7⅝″ high and ⅜″ joints contains 18 courses. How high is the wall?
2. Explain how to consider and plan the size and location for a window in a concrete masonry wall composed of 8″ x 8″x 16″ blocks.
3. What materials are generally used in making concrete blocks?
4. What is a plumb rule used for in the laying of concrete block walls?
5. What is the difference between regular and smooth concrete blocks?
6. What is meant by nominal block sizes?
7. What is the difference between random and coursed ashlar?
8. What is the difference between a slip and a lug type window sill?
9. Explain how to plan the length of a concrete block wall.
10. Explain how to plan the size and location of windows in concrete block walls.

11. How much bearing should joists have in walls?

12. Why should the ends of joists be beveled where they have their bearing in block walls?

13. Explain how to check the level of blocks as they are laid in walls.

14. Explain the steps required in the laying of a block wall without windows or doors.

15. Should mortar joints under lug sills be completed before the entire wall they are in is complete?

16. What kind of a concrete block is necessary for window jambs when casings are required?

CHAPTER VI

Structural Clay Tile

QUESTIONS CHAPTER VI WILL ANSWER FOR YOU

1. *How can tile be used for such purposes as making reinforced lintels and tile beams?*
2. *How is tile used in fireproofing, in wall draining, and as protection against termites?*
3. *How are tile walls designed and constructed?*
4. *What are some of the applications of the various surface finishes available in structural clay tile?*
5. *What are a few of the advantages to be gained through the use of structural clay tile?*

INTRODUCTION TO CHAPTER VI

The use of structural clay tile is universally recognized as an excellent type of construction for practically all types of buildings whether their walls be of brick veneer on tile, stucco on tile, or various kinds of painted, smooth-finish tile. Structural tile is light in weight, fireproof, ratproof, rustproof, termiteproof, immune to decay from contact with water or chemicals, and does not readily expand or contract due to temperature changes or water content. The use of structural clay tile assures economical construction costs and reduces the expense of upkeep, insurance, and depreciation. Finally, hollow tile walls, partitions, and floors have a low rate in gain and loss of heat which assures that houses and other buildings built of them will be warmer in cold weather and cooler in hot weather.

For the most part, the problems encountered in laying clay tile are similar to those found in working with concrete blocks. The chief difference is in the greater variety of uses to which tile may be put which results in many problems for the unskilled worker. These problems are carefully pointed out and effectively explained as they appear in the text.

When you have completed this chapter on clay tile you will have acquired an extensive general knowledge of the subject but a knowledge which requires actual practice in the use of clay tile to be of value to you. You will have learned of the general types of clay tile, end or side construction and load or nonload bearing, and their specific uses. You will have had described for you the various sizes and shapes of structural clay tile units and the uses to which they are put. You will have found descriptions of clay tile partitions, foundations, and floors and the use of clay tile in fireproofing and precast beams. As for concrete blocks, you will have seen how the dimensions of the clay tile ultimately determine the precise dimensions of the building they are used for

as well as the exact location of the windows and doors. You will have read details of wall and partition erection, noted the emphasis placed on clay tile corner construction, and the maintaining of the proper bond throughout the structure. You will appreciate the care taken in the description of the laying of a typical wall—how the corners are first built up, level and plumb, then the intervening wall laid with a string stretched between the corners for a guide. You will have read descriptions of corner and cornice construction and such minor but important items as flashing, metal ties, pilasters, nailing strips, wall draining, termite shields, door bucks, and many others. You will have discovered the careful manner in which the description of laying tile is presented. Finally, you will have been impressed by the large number of carefully prepared illustrations which help you visualize each step or point under consideration.

USE OF STRUCTURAL CLAY TILE

Structural clay tile is the term applied to various sizes and kinds of hollow and practically solid structural units which are molded from surface clay, shale, fire clay, or mixtures of these materials, and laid by masons. The standard physical properties for such structural units are set forth by the United States Government and by the American Society for Testing Materials in what are known as *Federal* and *Standard Specifications* for structural tile. These specifications can be secured free of charge and are recommended to anyone interested in selecting and buying structural tile units.

The purpose of this chapter is to describe some of the typical kinds of structural clay tile, to indicate the types of construction it can be used for, and to show and explain helpful and useful facts relative to textures, colors, wall patterns, mortar joints, planning, typical structural details, and erection procedures. Only structural clay tile is considered. In other words, only tile used to build foundations, walls, partitions, floors, and other structural members is explained.

The planning and laying of structural clay tile is greatly similar to the planning and laying procedures explained in the chapter on concrete masonry, in that both chapters are concerned with unit or block-type masonry. It is recommended that the concrete masonry chapter be read carefully before the study of this chapter is started.

KINDS OF STRUCTURAL CLAY TILE

There are many kinds of structural clay tile from the standpoints of recommended use, shapes, sizes, numbers of cells per unit, and ap-

pearance. It would be impossible to include all kinds of tile in this chapter, so only typical kinds are illustrated and explained as a means of presenting general instruction of value, no matter what specific kind of tile the reader intends using.

Side- or End-Construction Tile. Structural clay tile is designed and manufactured for use as end-construction or side-construction building units. End-construction tile is placed in a wall so that the cells are vertical. Side-construction tile is placed in a wall so that the cells are horizontal. See Fig. 1.

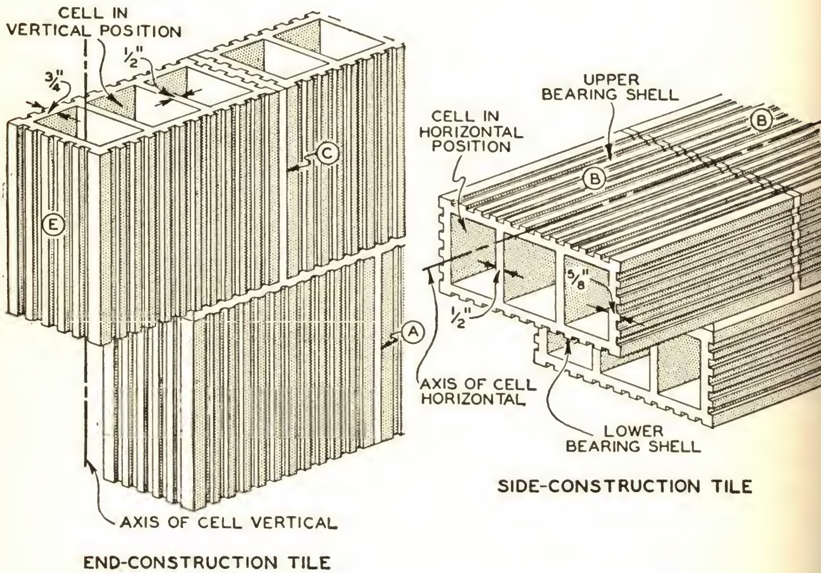


Fig. 1. End- and Side-Construction Tile

Load-Bearing Wall Tile. When any wall which supports loads other than its own weight is built of tile units with or without facing such as brick veneer or stucco, each of the tile units must be of a grade known as *load-bearing.* Such units are manufactured according to the Federal and A.S.T.M. Specifications previously mentioned.

Load-bearing tile units are made in two grades, namely, LB and LBX. The latter, sometimes called *load-bearing extra,* is used for all kinds of load-bearing walls (including foundations) and is adapted for use in masonry exposed to frost and weathering, providing it has

been burned to the normal maturity of the clay during its manufacture. This grade also may be considered suitable for the direct application of stucco. The LB grade of tile units is used for all kinds of load-bearing walls which are not exposed to frost action, or for use in exposed masonry when protected by a facing of 3″ or more of brick veneer, stone, or other masonry.

Physical Properties of Load-Bearing Wall Tile. The physical properties of structural load-bearing wall tile should conform to the requirements presented in Table I. In addition, load-bearing tile should conform to the requirements shown in Table II as to the number of cells in the direction of the wall thickness.

TABLE I. PHYSICAL REQUIREMENTS

Grade	Absorption* per Cent			Compressive Strength (Based on Gross Area),† psi			
				End-Construction Tile		Side-Construction Tile	
	Average of Five Tests	Individual Maximum	Individual Minimum	Minimum Average of Five Tests	Individual Minimum	Minimum Average of Five Tests	Individual Minimum
LB X	5 to 16	19	4	1400	1000	700	500
LB	5 to 25	28	4	1000	700	700	500

*The range in percentage absorption for tile delivered to any one job shall be not more than 12.
†Gross area of a unit shall be the total area including cells of a section perpendicular to the direction of loading. Re-entrant spaces are included in the gross area, unless these spaces are to be occupied in masonry by portions of adjacent units.

TABLE II. CELLS

Nominal Horizontal Thickness in Inches of Tile as Laid in Wall	Minimum Number of Cells* in Direction of Wall Thickness
4	1
6	2
8	2
10	2
12	3

*Cells are hollow spaces inclosed within the perimeter of the exterior shells, and having a minimum dimension of not less than ½″ and a cross-sectional area of not less than one square inch.

The *shell* of a tile unit constitutes its four sides which bound or surround the hollow interior or cells. See Fig. 2. The *webs* of a tile unit are the partitions between cells. The average over-all thickness of the shells, measured between the inner and extreme outer surfaces of end-construction load-bearing tile, should not be less than ¾ inch. The thickness of the webs should not be less than ½ inch. The average over-all thickness of the shells, measured between the inner and extreme outer surfaces of side-construction load-bearing tile, should

not be less than 5/8 inch. The thickness of the webs should not be less than 1/2 inch. See Figs. 1 and 2.

The width of any cell in side-construction tile, measured in the direction of wall thickness, should not exceed 4½ times the average over-all thickness of either the upper or lower bearing shells. If no cell in side-construction tile, measured in the direction of the wall thickness, exceeds 4 times the average over-all thickness of either the upper or lower bearing shells, the requirements for minimum shell and web thickness specified in the foregoing may be waived.

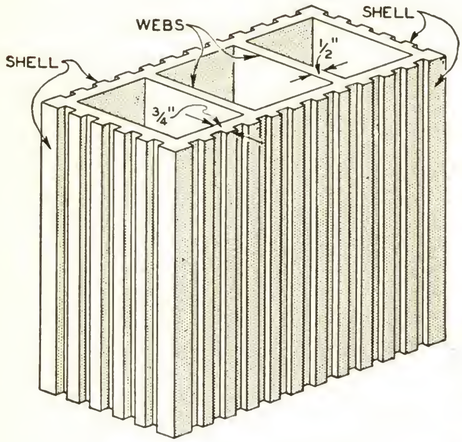


Fig. 2. Tile Shell and Webs

All tile must be reasonably free from laminations and cracks, blisters, surface roughness, and other defects that would interfere with proper setting of the tile or impair the strength or permanence of the construction.

TABLE III. AVERAGE WEIGHTS OF LOAD-BEARING STRUCTURAL CLAY TILE

Nominal Horizontal Thickness of Tile as Laid in Wall	Average Weight per Square Foot of Tile*
4	18
6	27
8	36
10	42
12	52

*The weights given in the table are for scored tile. For smooth, combed, or roughened finish, the weights should be increased 0.5 lb. per square foot of exposed area.

The average weights of load-bearing wall tile are given in Table III. These weights are for tile meeting the requirements for minimum thicknesses of shells and webs. However, weights are not mandatory requirements since many manufacturers produce tile with thicker shells than required by the minimum standard.

NONLOAD-BEARING WALL TILE. When any wall or partition supports no other loads other than its own weight, each of the tile units

used in its construction can be of a grade known as *nonload-bearing* or NB tile. Such units also are manufactured according to the Federal and A.S.T.M. specifications. Tile used for furring and fireproof construction can be of the nonload-bearing grade. However, if such tile is to be used for load-bearing masonry construction in addition to its use as a fireproofing material, it must be either LB or LBX grade tile.

Physical Properties of Nonload-Bearing Wall Tile. The physical properties of nonload-bearing structural wall tile should conform to the absorption requirements presented in Table IV.

TABLE IV. ABSORPTION REQUIREMENTS

Grade	Absorption* per Cent		
	Average of five tests	Individual Maximum	Individual Minimum
NB	5 to 25	28	4

*The range in percentage absorption for tile delivered to any one job should be not more than 12.

Weights for nonload-bearing tile are somewhat less than for the load-bearing tile but for ordinary purposes can be considered the same as given in Table III. The requirements for minimum weights of structural clay nonload-bearing units can be waived if the over-all thickness of the shells, measured between the inner and extreme outer surfaces, is not less than 5/8″ and the thickness of the webs not less than 1/2 inch.

Partition and split furring (explained in the following pages) tile should conform to the requirements set forth in Table V as to the total number of cells in the direction of wall thickness and dry weights per square foot of tile.

It is important that the over-all dimensions of this grade of tile do not vary more than 3 per cent over or under the specified dimension for any form or size of tile. As for load-bearing tile, units should be reasonably free from laminations and from cracks, blisters, surface roughness, and other defects.

Tile Markings. All structural clay tile, whether load or nonload bearing, should be clearly marked with the words "load-bearing" or "nonload-bearing" or the symbols "LBX," "LB," or "NB." In addition, each unit should bear the manufacturer's name, initials, or trademark.

Common Tile Units. It should be understood that common tile units are those which have not been especially finished insofar as their appearance, texture, and surfaces are concerned. The units ordinarily employed for load- and nonload-bearing walls, for example, are generally of the common type unless otherwise specified. In fact, all tile, as usually specified, is common tile unless special and additional descriptions are given. In this book, unless otherwise noted, all tile explanations have to do with common tile.

Table V. Number of Cells and Weight of Tile

Dimensions in Inches	Minimum Number of Cells		Minimum Weight* Lb. per Sq. Ft. of Tile	
	In Unit	In Direction of Wall Thickness	Average	Individual
Partition Tile				
2 by 12 by 12	3	1	14	13
3 by 12 by 12	3	1	15	14
4 by 12 by 12	3	1	16	15
6 by 12 by 12	3	1	22	21
6 by 12 by 12	4	2	25	24
8 by 12 by 12	4	2	30	28
10 by 12 by 12	4	2	35	33
12 by 12 by 12	4	2	40	38
Split Furring Tile				
1½ by 12 by 12	3	..	7½	7
2 by 12 by 12	3	..	8	7½

*The weights given in the table are for scored tile. If any of the faces are unscored, the weights shall be increased 0.5 lb. per square foot of unscored area.

Scored Tile Units. If plaster or stucco is to be applied directly to the surfaces of a tile wall or partition, the surfaces must be scored or grooved to provide keys to hold the plaster or stucco in place. Figs. 1, 2, and 3 illustrate such scored and grooved tile units. Common and face tile units may be obtained with either one or two faces and both ends scored or grooved in order that walls may have a plain exterior and a plastered interior or a stucco exterior and a plain interior, etc. If tile units are used for backing brick or stone veneer, the face of the units against the veneering should be scored or grooved.

Grooves should not be less than ⅛″ nor more than 3/16″ in depth nor more than 1″ in width. The area covered by the grooves should not exceed 50 per cent of the area of the scored faces.

Ordinarily, an order to a tile dealer for units of given sizes would

be filled with units having scoring on all four sides. If units having one smooth side were required, they should be ordered by the designation, S-I-S-I-E.

Smooth Tile Units. For walls and partitions where no veneering, stucco, or plaster is required, units, either common or face, may be used which have smooth faces. Common-type smooth tile units are reasonably free from blemishes although acceptable units may have *small* blisters, cracks, or warping which are not objectionable for such structures as barns, milkhouses, or small garages. When ordering smooth tile, use the designation S-4-S which means smooth on all

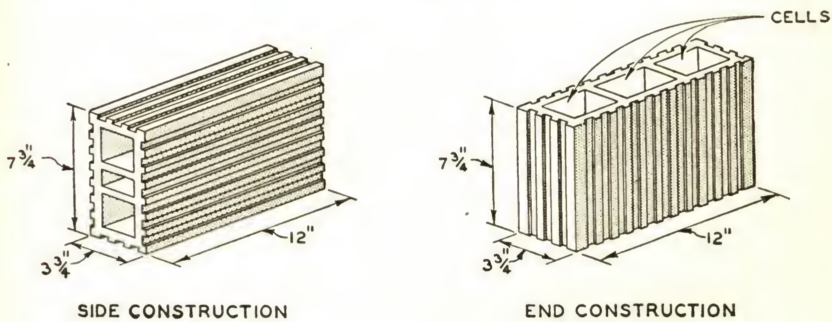


Fig. 3. Recommended Tile Dimensioning

four sides. When unscored or smooth tile is used, the requirements, except for the scoring, should be the same as for scored tile.

FACE TILE UNITS. Sometimes special types of tile known as *face tile* are employed in the construction of residences, barns, and other buildings. Such tile have their exposed surfaces especially treated to add to their appearance, to add color, make them more resistive to weathering, acids, etc. This type of tile is always called *face* or *glazed* tile in order to distinguish it from common tile.

CORED-SHELL UNITS. Thus far in this chapter, the tile units discussed have been of the hollow variety having cells as noted in the end-construction unit shown in Fig. 3. Sometimes, for specific purposes explained in the following pages, tile units are practically solid, thus providing an extra strong unit. Such units as shown in (B) of Fig. 8 have small and narrow openings in them which are called cores. Some regularly celled units, as shown in (D) of Fig. 8, have extra thick

shell walls in which smaller sized cells or cores are made. Such units also possess extra strength for use where extra wall or partition strength is required.

DIMENSIONS OF TILE

In the past, there has been a great deal of confusion on the part of the tile manufacturers and users as to the proper method of designating the dimensions for structural clay hollow tile. To overcome such confusion, the following method of tile unit dimensioning is recommended:

The first dimension is the through-the-wall thickness of the tile unit.

The second dimension is the closure side at right angles to the thickness.

The third dimension is the cut dimension and is the most important as it controls the unit's use as a side- or end-construction tile.

A tile measuring 3¾″ thick, 7¾″ high, and 12″ long is, as shown in Fig. 3, a side-construction tile (cells run horizontally) and should be designated as 3¾″ x 12″ x 7¾ inches.

A tile measuring 3¾″ thick, 12″ long, and 7¾″ high is, as shown in Fig. 3, an end-construction tile (cells run vertically) and should be designated as 3¾″ x 12″ x 7¾ inches.

Even though the units shown in Fig. 3 are of exactly the same size, they are not interchangeable and exhibit the importance of proper dimensioning.

Shapes and Sizes of Structural Clay Tile Units. Figs. 4 through 8 show typical shapes and sizes of structural clay tile units. It should be understood that the units illustrated and explained in the following are presented only as *typical* shapes and sizes. There are many other shapes and sizes available in various parts of the country which serve the purposes equally as well and can be used following the general instructions in this chapter. In the section on typical structural clay tile construction of this chapter, other shapes and sizes are shown.

(A) of Fig. 4 is a three-celled partition tile used only in partitions which divide floor space into rooms and do not carry any loads other than their own weights.

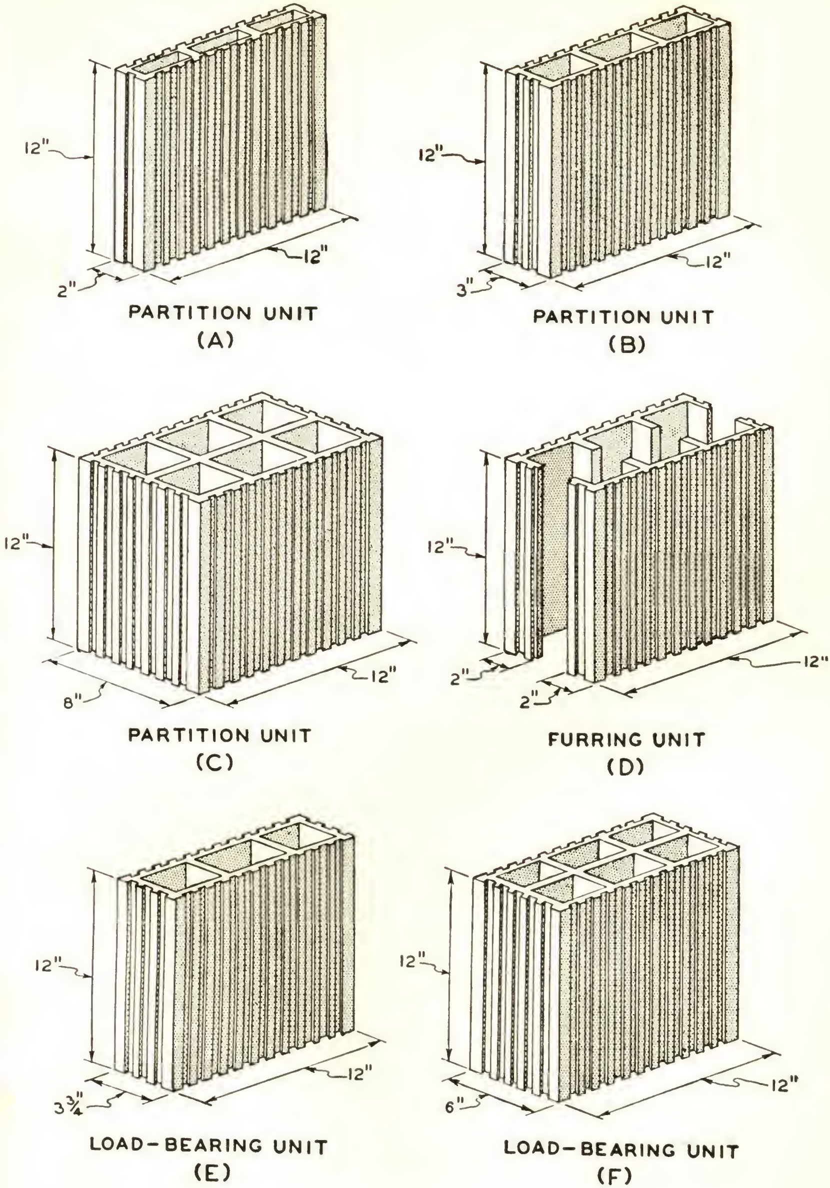


Fig. 4. Typical Shapes and Sizes of Structural Clay Tile Units

(B) of Fig. 4, like the unit at (A), is also a partition tile subject to the same limitations. Note that it is 1″ thicker than the unit shown at (A) and that it has 2 end grooves (scoring) instead of one. Similar units 4″ and 6″ thick having 3 and 5 end grooves also can be obtained.

(C) of Fig. 4 is a six-celled partition block subject to the same limitations. Similar units 10″ and 12″ thick and having 8 and 10 end grooves can be obtained.

(D) of Fig. 4 is a furring unit employed, for example, on the interior surface of brick, concrete, or other masonry wall as a means of providing a grooved surface for plaster application and also as a means of providing an air space between the plaster and the main wall. Furring units also may be placed around structural members as fireproofing.

(E) of Fig. 4 is a unit similar to the partition unit shown at (A) except for the thickness dimension and the thickness of shells which for load-bearing units are generally greater.

(F) of Fig. 4 is a six-celled load-bearing unit which differs from the unit in (E) in the number of cells and end grooves. Similar units 8″, 10″, and 12″ thick having 6, 8, and 10 end grooves also can be obtained.

(A) of Fig. 5 is a load-bearing unit used to form the inner wythe of a 9½″ cavity wall. These units course out with three courses of standard size brick.

(B) of Fig. 5 is a unit used to form either an 8″ or a 5″ wythe for a cavity wall. It can also be used to build load-bearing partitions.

(C) in Fig. 5 is another unit for use in the inner wythe of a cavity wall. It courses out with four standard size brick.

(D) of Fig. 5 is a corner closure unit used for forming corners and jambs. The unit has frequent use in the construction of various kinds of solid tile load-bearing walls.

(E) of Fig. 5 is another type of corner closure which can be split to form three different lengths as indicated by the dimensions. This unit can be used wholly or in part in many types of tile walls.

(F) of Fig. 5 is a load-bearing unit which can be used to form the inner wythe of a 9½″ cavity wall. It courses out with two standard size brick. It can be secured in lengths of 8″ as well as the illustrated 12 inches. This type of unit is sometimes used to build

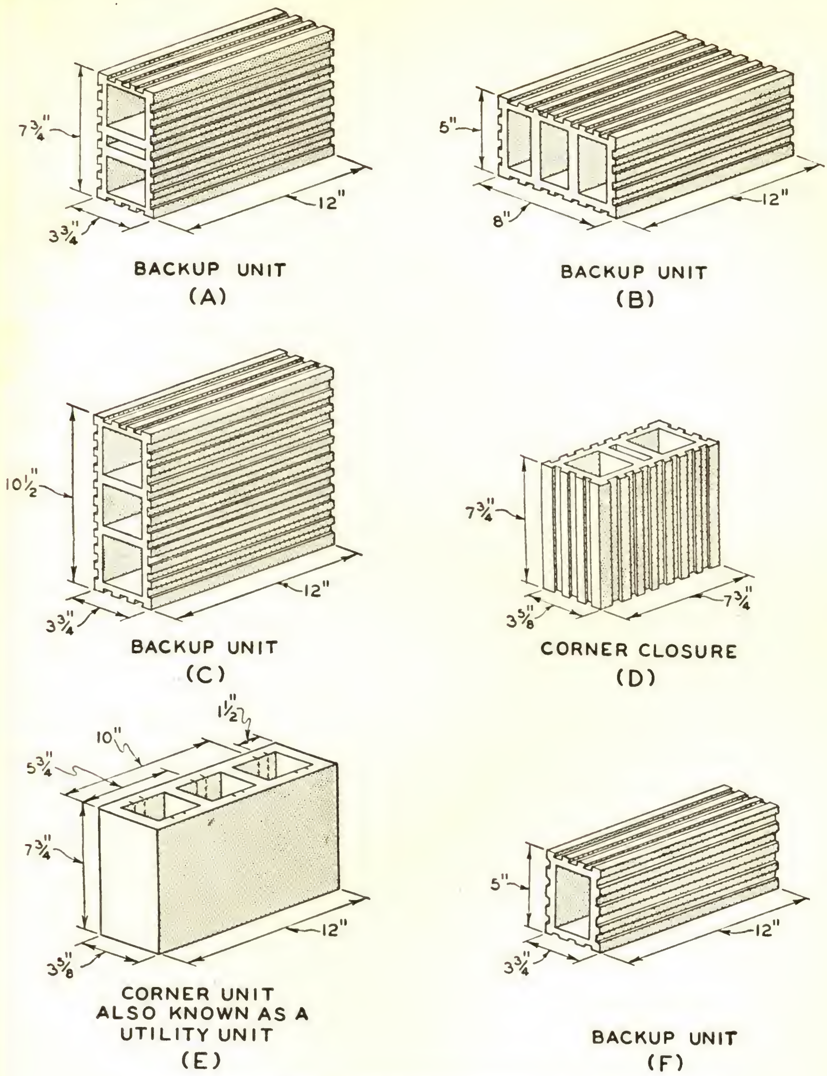


Fig. 5. Typical Shapes and Sizes of Structural Clay Tile Units

all-tile cavity walls and as a substitute for 3″ or 4″ drain tile for septic tank disposal lines. When building all-tile solid walls, this unit is called a stretcher.

(A) of Fig. 6 is a unit typical of the jamb units used in connec-

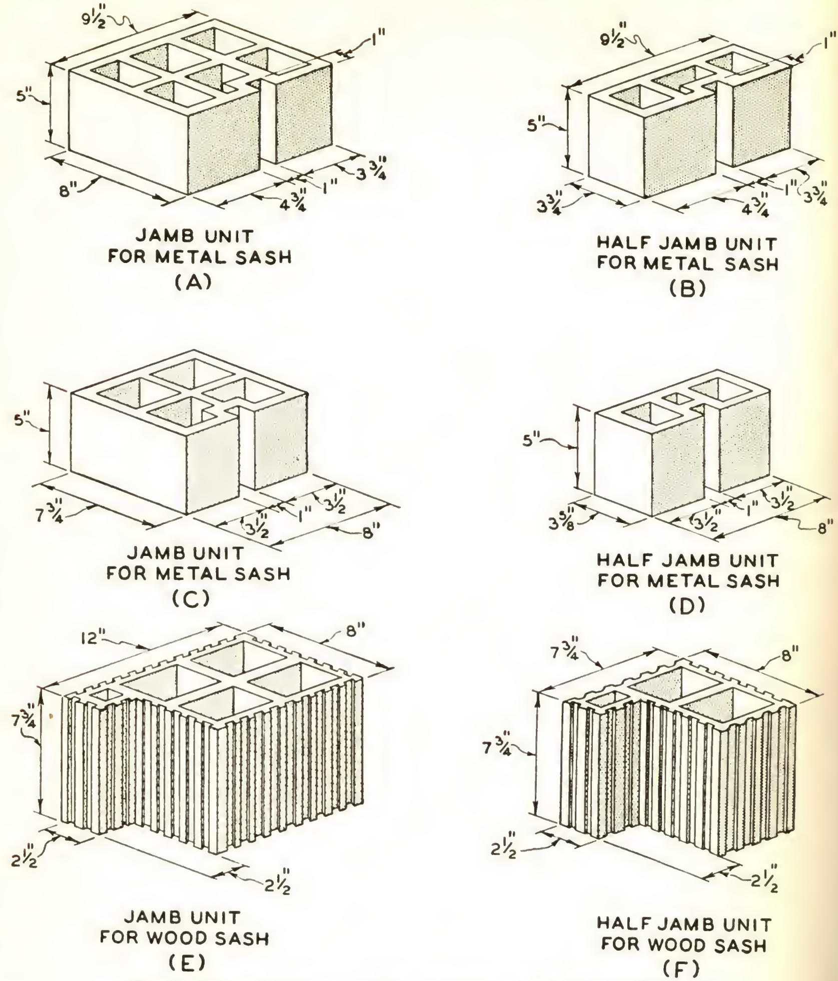


Fig. 6. Typical Shapes and Sizes of Structural Clay Tile Units

tion with metal sash windows. Note that this unit is for a 10″ solid tile wall.

(B) of Fig. 6 is a half jamb unit similar to the unit shown at (A) except only half as large. It is used around jambs and as headers in 10″ solid tile walls.

(C) of Fig. 6 is another jamb unit having only four cells and for use with steel sash windows in solid tile walls. Other units 7¼″ high can be obtained.

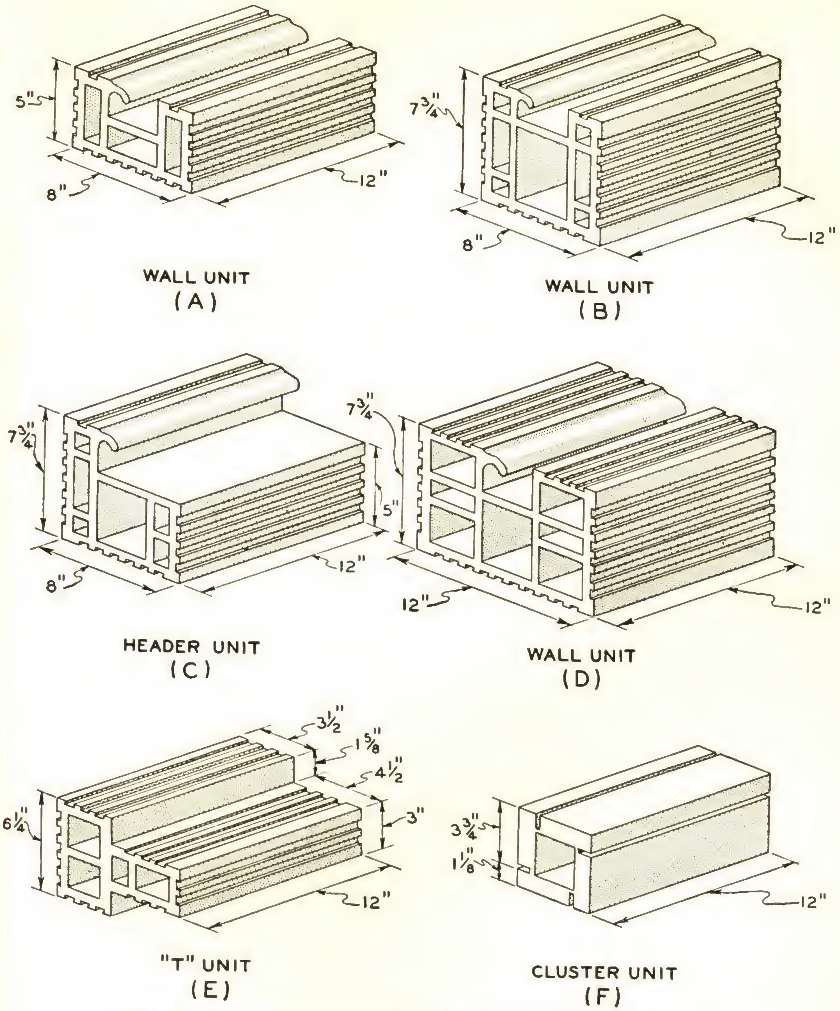


Fig. 7. Typical Shapes and Sizes of Structural Clay Tile Units

(D) of Fig. 6 is a half jamb unit used around window jambs and as corner closures in solid tile walls. Other units 7¼″ high can be secured.

(E) of Fig. 6 is a typical jamb unit for wood sash windows. Similar units only 5″ high can be obtained.

(F) of Fig. 6 is still another jamb unit for wood sash windows in solid tile walls. Similar units only 5″ high can also be obtained.

In regard to jamb units for either metal or wood sash windows in solid brick walls, it should be understood that various manufacturers produce many different sizes and shapes peculiar to their own particular types of units. And, as previously mentioned, the units may be obtained scored or smooth.

(A) of Fig. 7 is a unit usually used in solid tile load-bearing walls. The units shown at (A) and (B) in Fig. 6 can be used with this unit as jambs and closures in wall construction. Note that this unit has a handle for use in wall construction. Corner closures which are 5″ high and similar to the unit shown in (E) of Fig. 5 also are used with this unit in walls.

(B) of Fig. 7 is another typical wall unit. It can also be secured having 8″ x 7¾″ x 7¾″ dimensions. This unit is generally used in solid tile walls.

(C) of Fig. 7 is a unit especially adapted for use in solid walls having brick facings and in sill construction. Similar units can also be secured in 7¾″ and 3¾″ lengths.

(D) of Fig. 7 is another solid tile wall unit for 12″ walls. Similar units 3¾″ and 7¾″ long can also be secured. Headers, of the same cell design and similar in shape to the unit shown at (C), can be obtained in 3¾″, 7¾″, and 12″ lengths.

(E) of Fig. 7 is a unit used for solid tile walls and in connection with brick veneer masonry. Similar units 3¾″ (⅓ unit) and 7¾″ (⅔ unit) long can be secured.

(F) of Fig. 7 is a unit used with **T** units to fill space of starting points of walls. Closure units measuring 3⅝″ x 3″ x 8″ can also be used along with this cluster unit.

(A) of Fig. 8 is a jumbo unit typical of many other such special kinds of tile used for residence and other high-class construction. They resemble oversize bricks and when built into a wall make an excellent appearance. Closures, to be used with this unit, are available.

(B) of Fig. 8 is the so-called C. J. unit extensively used in sills, jambs, and other places where added strength is required. Such units can be secured in various sizes to fit the needs of various other shapes and sizes of units it may be used with. This unit is a general utility unit.

(C) of Fig. 8 is a typical example of double-shell units previously mentioned. (D) of Fig. 8 is a typical example of cored-shell

units previously mentioned. (E) of Fig. 8 is one of several different shapes of units used in the construction of flat arch floors. Its peculiar shape allows it to fit around the flanges of **I** beams. (F) of Fig. 8 is a typical fireproofing unit. Its shape allows it to fit around and cover the flange on one side of an **I** beam.

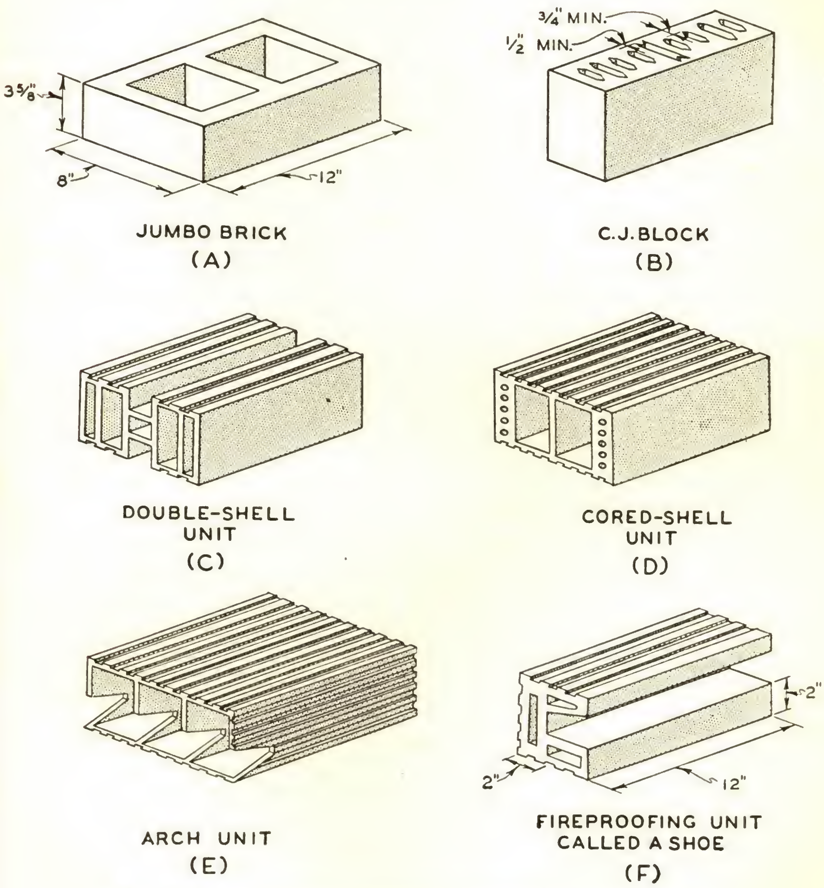


Fig. 8. Typical Shapes and Sizes of Structural Clay Tile Units

Actual and Nominal Unit Sizes. The dimensions shown for the various units illustrated in Figs. 4 through 8 are *actual* dimensions. All tile units, if well constructed, will be consistent in those dimensions with but a small degree of possible error. Sometimes units are

referred to by dimensions which are not actual measurements. For example, a 3¾″ x 7¾″ x 12″ unit may be called either 4″ x 8″ x 12″ or 3″ x 7″ x 12″ for the sake of ease in speaking or writing. Such practice is not recommended because the actual dimensions must be considered when planning walls or other masonry work. Using the approximate or nominal dimensions tends to make more error in planning and laying.

Not all unit manufacturers use exactly the same general sizes in producing units. Therefore, the closures, backing, and other smaller and utility unit sizes should be carefully ascertained prior to planning walls or other masonry work. It is also a good idea to use only one manufacturer's units on any one particular job. This practice avoids unsightly work and faulty bonding.

Mortar joints can be from ¼″ to ½″ in thickness. Unit sizes are fractional in many instances to allow for the mortar joints. Thus, a unit 7¾″ high becomes exactly 8″ when a ¼″ joint is used.

TYPICAL USES FOR STRUCTURAL CLAY TILE

Walls. Walls made of structural clay tile are built using load- or nonload-bearing units having one or many cells, single or double shells, divided mortar joints, and flat or irregular beds. The tile may be glazed or natural, rectangular, square, or curved.

Tile walls can be used for residences, barns, silos, milkhouses, poultry houses, and various other kinds of masonry structures. Such walls are strong and possess many desirable features including quick erection, barriers to moisture, heat, and cold, and extreme durability and stability.

The storage elevator in Fig. 9 is an excellent example of tile construction. Additional material concerning walls will be found under tile construction details in this chapter.

Partitions. Tile partitions are greatly similar to tile walls except for their thickness. Generally, they are from 2½″ to 6″ thick, depending on whether or not they must support loads in addition to their own weight, plumbing fixtures, etc. Partitions are frequently made thicker than structural requirements demand in order to conceal plumbing pipes, heating ducts, clothes chutes, etc., but the thickness should always be in multiples of 2, such as 4″ and 6 inches.

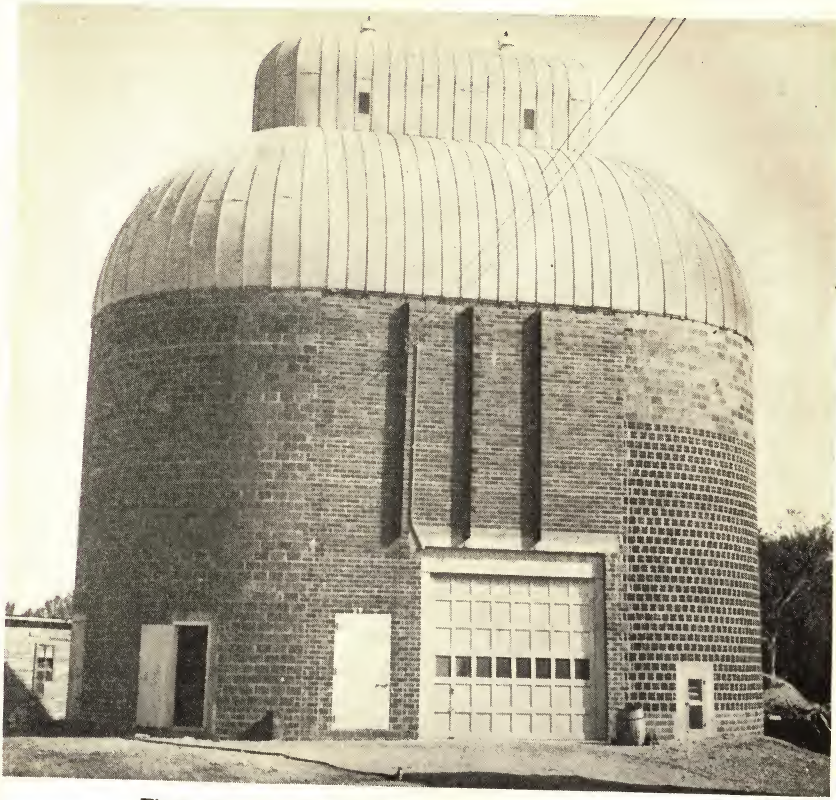


Fig. 9. Combination Brick and Clay Tile Storage Elevator

Tile partitions can be used in any building where they will be supported by steel or concrete beams or concrete floors. They should never be used where their support depends on wood framing or floors (see Fig. 25).

Foundations. Tile used for foundations should conform to the requirements for grade LBX tile as presented in the American Standard Specifications for Structural Clay Load-Bearing Wall Tile.[1] Tile of this specification safely can withstand frost, moisture, and other soil conditions for which other classes of tile are not designed and manufactured. When correct tile and proper mortar are used, tile foundations serve the purpose as well as foundations built of other materials.

[1] Copies of these specifications can be secured from the American Society for Testing Materials at Philadelphia, Pa.

Generally, foundation tile having thickness of 5″, 8″, 10″, or 12″ with lengths of 12″ or 16″ are used. Fig. 10 illustrates the use of such tile. Mortar for use with tile foundations should be a mix of one part Portland cement and three parts sand or a like mix with from 0 to ¼ part hydrated lime or lime putty added to it.

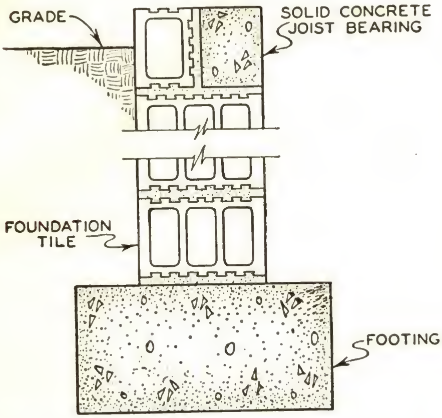


Fig. 10. Foundation Having a Thickness of Five Inches Constructed of Load-Bearing Tile

Tile foundations are extensively used in connection with tile farm structures. For such foundations, the depth is only enough to be definitely below the frost level.

Floors. Following walls, partitions, and footings, the next most important use for tile units is probably for various kinds of floors. Fig. 11 shows one of the simplest ways of using tile units to form a basement or barn floor over an earth fill. The use of such units in a floor is insurance against moisture penetration and makes for a dry floor. Fig. 12 shows the use of tile units in concrete floor construction. The use of the units in such floors is economical and strong. The use of tile units in arched floor construction is shown in Fig. 13. This type of masonry work is always used in connection with buildings which have steel framing. Many other types of flooring using a variety of other shapes and sizes of units are possible.

Fireproofing. The steel framing members used in fireproof buildings should be carefully fireproofed. The idea back of fireproofing steel beams, columns, etc., is to keep fire and excessive heat away from the steel. If steel is heated to a cherry red color, it will bend and thus fail as a structural member. Fig. 13 shows how an **I** beam can be fireproofed using structural clay tile units. These units serve the purpose to excellent advantage and at the same time add to the architectural appearance as well as provide a plaster base. Units to encase all steel shapes and sizes are available.

Precast Tile Beam. Fig. 14 shows a typical precast tile beam. Note that tile units are used together with mortar and reinforcing steel to make the beam. These beams can be made on the job to any desired length and can be used as lintels and for floor and roof supports in

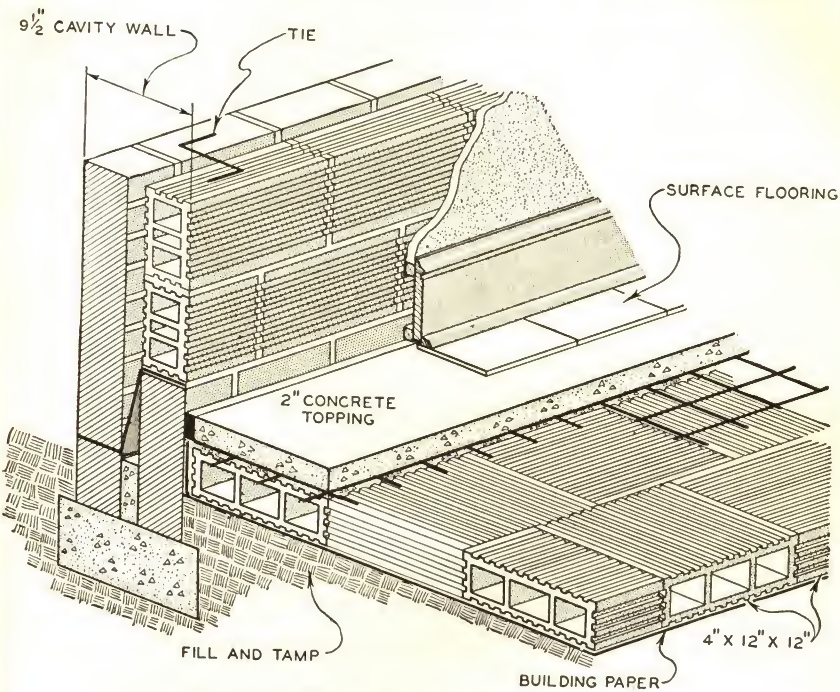


Fig. 11. Tile Units Used in Floor over Earth Fill

the same manner as any ordinary beam. Special tile units can be used to fill the space between the tile beams.

SURFACE FINISHES AND COLOR

Most tile units commonly used in walls, partitions, beams, and foundations have no special finish other than that produced in the molds at the time of manufacture.

Glazed Units for Interiors. Glazed units for interior wall surfaces may be obtained having very smooth surfaces and in a variety of colors. Such units are used generally for dairy building walls, for recreation rooms in residences, and other places where a wall surface

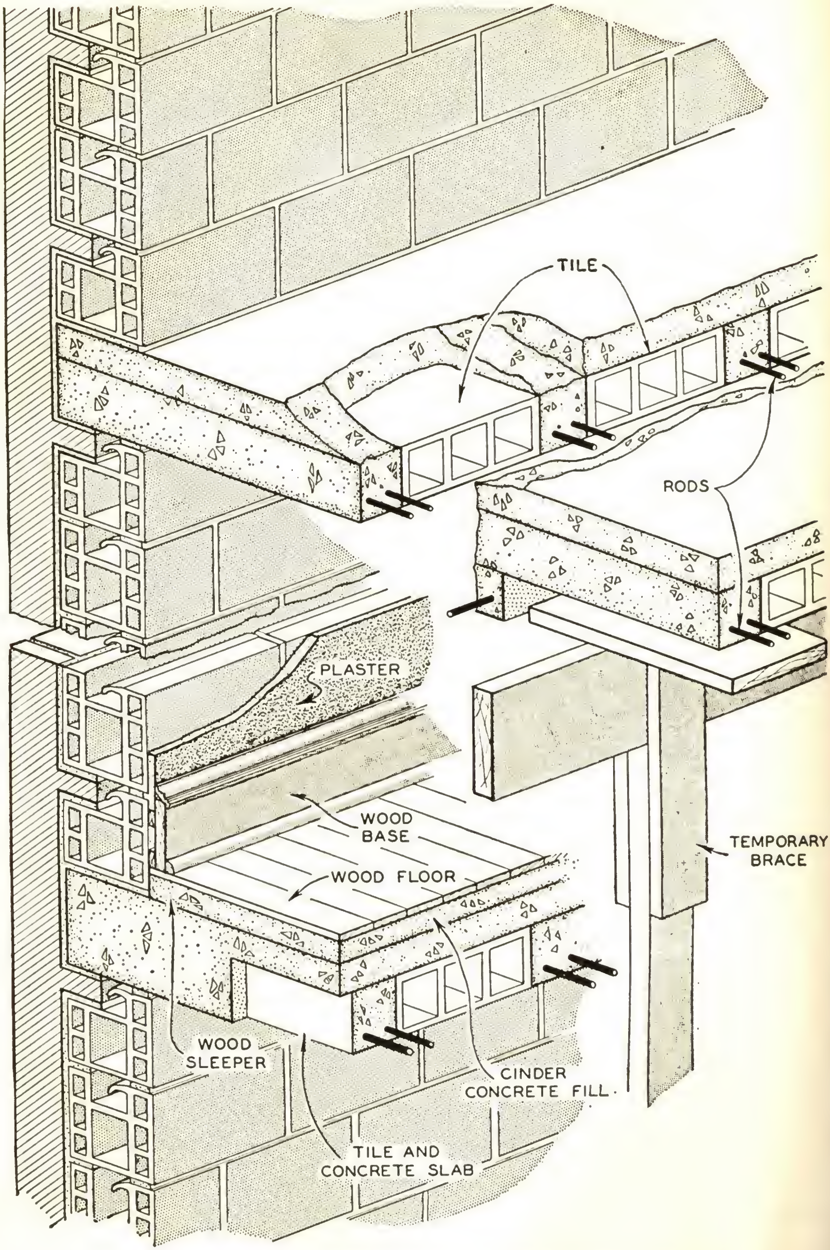


Fig. 12. Tile Units Used in Concrete Floor Construction

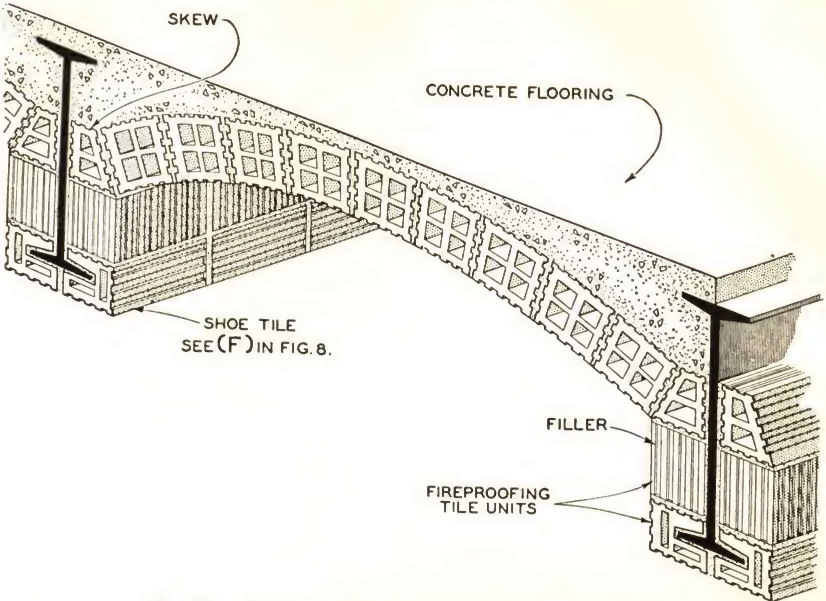


Fig. 13. Tile Units Used in Arched Floor Construction

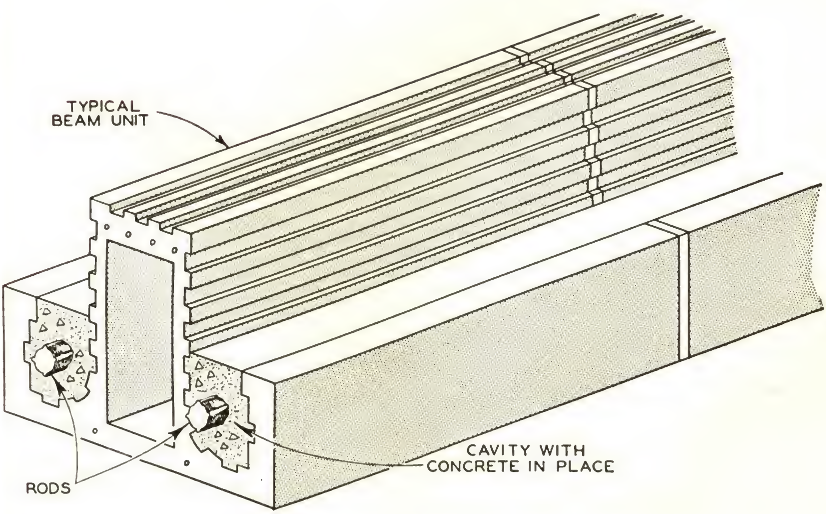


Fig. 14. Typical Precast Tile Beam

is required which is easy to clean and especially good in appearance.

Glazed Units for Exteriors. Glazed units for exterior wall surfaces are also available. Some such units, known as *face* tile, have surfaces which are smooth and may be obtained in any of several colors. Others, finished to resemble rock, also are available in many colors.

Brick Surfaces. Some units, such as the jumbo unit shown in (A) of Fig. 8, are made to resemble various face brick finishes and colors.

Color. Some manufacturers will produce tile units of a specified color by special order from purchasers. Special coloring can be produced in practically any style unit, but at extra cost.

All manufacturers of tile units have descriptive literature relative to surface finishes and color with which they will gladly supply any interested party. It is recommended that such literature be carefully studied and visits made to building material sales yards when planning the use of tile units, especially when a particular surfacing or color is desired.

WALL PATTERNS AND BONDING

The ashlar wall patterns explained in the chapter on concrete masonry are not possible in structural clay tile walls because the tile units are not as varied in shapes and sizes and because tile construction is not adapted to the creation of such pleasing patterns. For the most part, solid tile walls are no more decorative so far as pattern is concerned than those built of ordinary concrete blocks. The use of the smaller units, such as shown in (A) of Fig. 8, creates a brick pattern, but beyond that no decorative patterns are possible.

Some relief from plain patterns may be had by using one size of unit part way up a wall and a second size to complete the top portion or one or more courses can be laid with units placed end-construction instead of side-construction. Where face units are used, some pattern may be accomplished by using a combination of finish or color, or both.

Bonding. As explained in the concrete masonry chapter, bonding must be carefully planned, then carried out during construction. Joints must be staggered and the various units, especially in veneered walls, carefully placed in all cases to obtain strength and satisfactory pattern. The various illustrations in the typical construction details

section of this chapter show recommended bonding for many typical masonry constructions.

Mortar and Joints. The explanations presented in the mortars for unit masonry and concrete masonry chapters apply equally as well to tile units and should therefore be reviewed in connection with this chapter.

Side Construction Versus End Construction. Practically all architects and engineers agree that side-construction tile has decided advantages over end-construction tile. One of the outstanding advantages is that in side-construction tile, all the vertical webs and shells are in good alignment. The horizontal mortar bed necessarily assures a full mortar joint between all the vertical shells and webs with the result that nearly 100 per cent load-bearing efficiency is possible. Another advantage is the fact that an interrupted mortar joint is possible with tile cells horizontal, whereas it is not with tile cells vertical.

Double Pointing. In masonry walls where two or more thicknesses of clay masonry make up the wall thicknesses, as in brick veneer walls on tile backups, the facing units (bricks) should be laid up ahead of the backup tile units. Then, the inner mortar joint of the facing units should be well pointed before the backup units are laid. Pointing both sides of the joints between facing units makes for added protection against moisture penetration. This practice requires more labor time but is well worth the additional cost.

TYPICAL STRUCTURAL CLAY TILE CONSTRUCTION DETAILS

In order to understand how various tile walls are actually designed and erected, it is necessary to be familiar with the common details of such construction work. The following discussions include commonly encountered details and will serve as a basis for all tile planning and laying.

Unit Planning. The unit planning details explained in the concrete masonry chapter illustrated the general method to be followed in planning block walls. That procedure is quite simple because of the few different shapes and sizes of blocks. The planning of tile units in walls, while following the same general principles, is more intricate because of the great many different unit sizes and shapes produced

by the various manufacturers and because more planning is required to use satisfactorily whatever type of units are available.

WALLS. Walls made of common tile units cannot always be planned to obtain the regular spacing of vertical joints which can be obtained in concrete block walls. However, if tile walls or partitions are to back up veneers or stucco and to serve as plaster bases, uniform spacing of vertical joints is not necessary beyond the requirement of staggered joints. In such cases, units can be cut to any convenient lengths or odd lengths of units can be used. If a tile wall is not to be surfaced or plastered, then the best possible appearance, from the standpoint of vertical joint regularity, should be planned. In the following explanations, it is assumed that the walls are not to be surfaced on the outside.

Before wall or partition lengths, window and door locations, and heights are determined, it is wise to learn what manufacturer's tile is available. All manufacturers, while using about the same general dimensions, vary in the closures and jambs they produce. Once the thicknesses, heights, and lengths of available units are known, wall planning can be carried out to much better advantage.

Suppose, for example, that a small milkhouse is contemplated and that tile units of the style shown in (A) of Fig. 7 and in (C) and (D) of Fig. 6 were available. Further, suppose that the over-all dimensions for the milkhouse should not be more than 15′ long and 12′ wide. This means that the end walls will each be about 12′ long.

The unit shown at (A) in Fig. 7 is 8″ thick, 5″ high, and 12″ long. Half jambs, as shown at (D) in Fig. 6, can be used as corner closures and these are 3⅝″ thick, 5″ high and 8″ long. Utility closures, similar to the one shown at (E) in Fig. 5, are 3⅝″ thick, 5″ high, and can be either 2″, 5¾″, 10″, or 12″ long. The exact wall lengths should be such that these units can be used without cutting other than the utility unit and so that the vertical joints are as uniform as possible.

The length of one end of the milkhouse when changed to inches is 12″ × 12″ or 144 inches. Each stretcher unit, see (A) in Fig. 7, is 12″ long. Therefore, dividing 144 by 12 gives 12, which means that 12 units would be required. However, the corners must be closed with closure units as shown in Fig. 15. Since it would be better to have the wall less rather than in excess of 12′, it can be seen that 12

stretcher units cannot be used. Even 11 stretchers would be too many. Ten stretchers plus the two closures would probably just about serve the purpose.

Fig. 15 shows what can be assumed as the first course above the

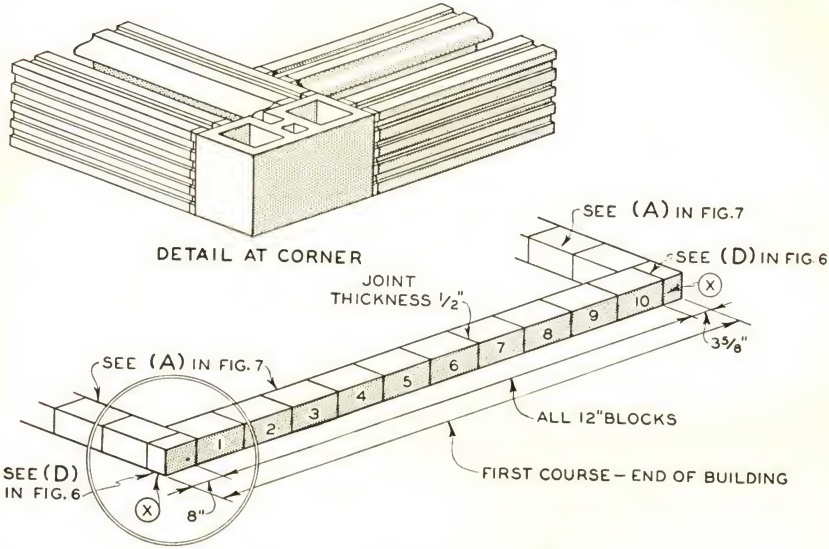


Fig. 15. First Course in a Carefully Planned Wall

foundation for one end wall. There are 10 stretchers and the two closure units which are indicated as X. They add up as follows:

stretchers—	$10 \times 12'' =$	$120''$
closure (left end)—	$=$	$8''$
closure (right end)—	$=$	$3\frac{5}{8}''$
$\frac{1}{2}''$ joints	$11 \times \frac{1}{2}'' =$	$5\frac{1}{2}''$
	Total	$137\frac{1}{8}''$

Since $137\frac{1}{8}'' \div 12$ gives almost $11\frac{1}{2}$ feet, the $11'6''$ length is satisfactory. This method of determining exact lengths for walls, according to units to be used, can be used for determining the length of any tile wall in any kind of building.

Fig. 16 shows how the second course for the end wall should be planned. Note that the positions of the closure units have been reversed to obtain staggered vertical joints. The vertical joints do not occur over the midpoints of the units below, but the arrangement is

satisfactory from the standpoint of bonding and appearance. All other courses should be planned in like manner.

WINDOWS. Tile wall openings for windows must be planned equally as carefully as the lengths of the walls in order to preserve good bond

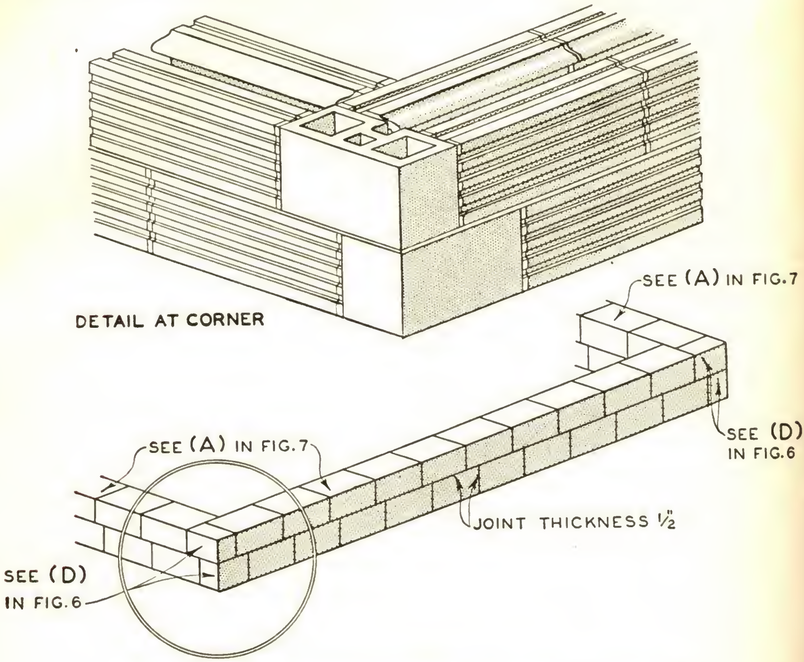


Fig. 16. Second or Alternate Course in a Carefully Planned Wall

and appearance and in order to avoid cutting tile other than the utility units which are especially made so that they can be cut to fit odd requirements.

Both steel and wood sash windows are produced in many standard shapes and sizes, any one of which can be purchased ready to assemble and install. The designer of any building must decide on window shapes and sizes. Suppose, for example, that the milkhouse previously mentioned must have one window in each end wall, that the windows should be about 30″ wide and equally as high, that their sills should be about 2′ above the foundation, and that they should be about 3′ from the corners of the milkhouse.

The stretchers in the wall are each 5″ high and the joints are ½″

thick. Therefore, as shown in Fig. 17 (Fig. 17 is for the same wall as shown in Figs. 15 and 16), five courses above the foundation would be about the place for the sills because those courses constitute a height of approximately 27½″ above the foundation.

In order to plan the exact distance the openings are from the corners, various unit combinations must be tried. This can be shown best by studying Fig. 17. Note course 6 between the window opening and the corner. This course is composed of the following units:

Unit *E* is a half jamb unit whose end is 3⅝″ across. Units *F* and *G* are regular stretchers whose combined lengths equal 24 inches. Unit *H* is 7¾″ long.

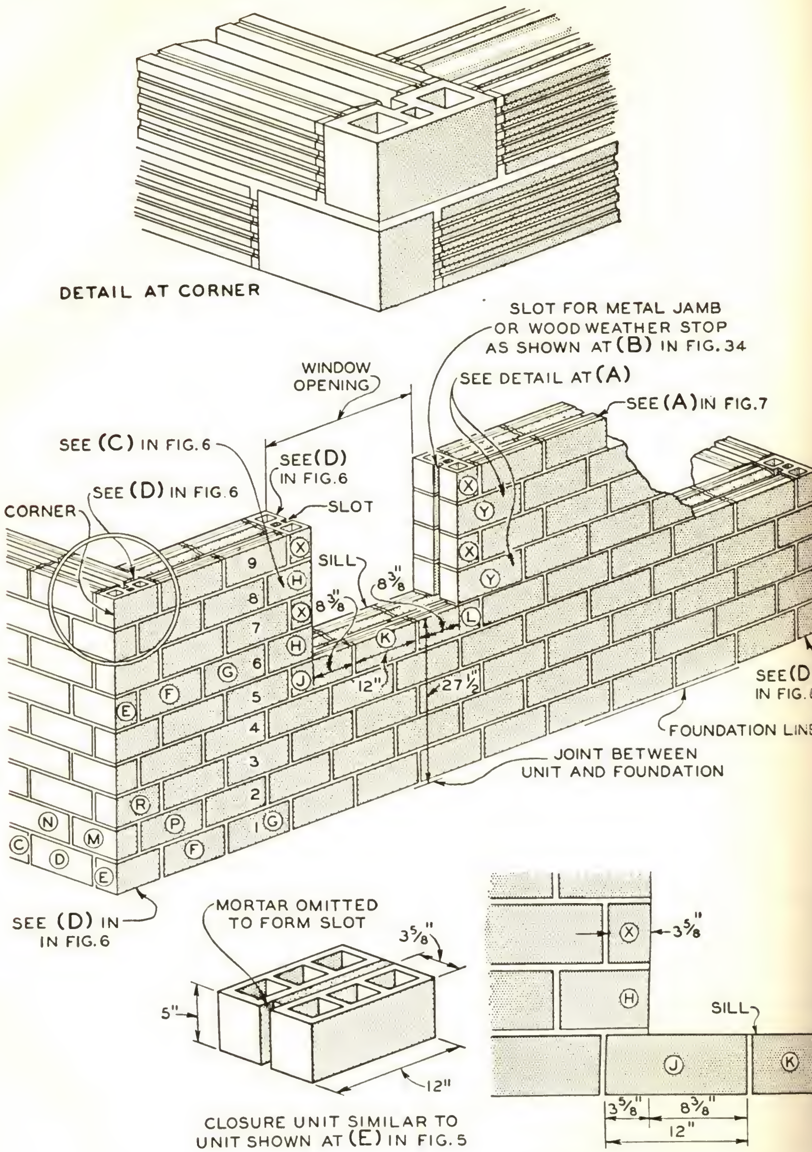
Adding the combined lengths of these units and three mortar joints gives a total of 36⅞ inches. This is only slightly more than the desired 3 feet. This distance must be used, as it is as close to 3′ as can be accomplished. Note how courses 7, 8, and 9 are fitted into the required length using the same units as elsewhere in the wall.

The window opening width, as indicated by units *J*, *K*, and *L* in course 5, is 28¾ inches. The 8⅜″ lengths are established as indicated in sketch (B) of Fig. 17. This is close to 30″ and a standard steel sash window will fit. The heights of windows must be in terms of 5½″ multiples because of stretcher and joint thicknesses. In Fig. 17, five courses allow a window height of 27½″, six courses 33″, etc.

By experimenting with various window sizes and different unit combinations, window openings can be planned satisfactorily. The procedure is one of trial and error until a satisfactory combination has been determined. Note that the wall in Fig. 17 is good in appearance, that all vertical joints are properly staggered, and that with the exception of the utility units, whole units are used exclusively. When walls are to be faced and plastered, the units can be planned so as to maintain staggered joints without regard for appearance. However, cutting of regular units should be avoided as a measure of economy.

The openings for doors and runways in tile walls are planned following the same general procedure as explained for windows.

Corner Construction. The corner construction shown in Figs. 15, 16, and 17 is typical where large size units are employed. Fig. 18 shows satisfactory corner construction where small units, such as



(A) (B)

Fig. 17. Window Location Must Be Considered in Unit Planning

shown in (A) of Fig. 8, are used. Every manufacturer of tile units includes various types of closure units in his line so that proper corner constructions always can be planned. With small units where Flemish and other brick bonds can be used, the closures serve the purpose of headers in laying the pattern.

Fig. 19 shows corner and jamb construction where tile such as shown in (E) of Fig. 7 and standard brick-sized cored units are used. The narrow and wide faces of the **T** units combine to form a pleasing bond and the closures at the corners and jambs add enough detail to make the wall pattern almost ashlar in appearance. With carefully

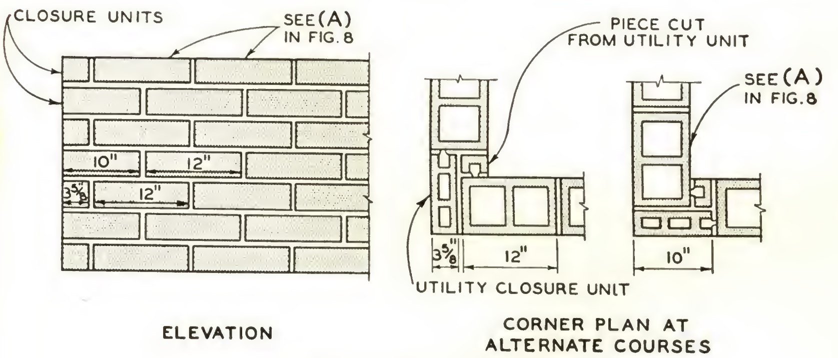


Fig. 18. Typical Corner Construction

pointed mortar joints, such a wall adds to the good appearance of any structure.

Flashing. One important item to remember is that no flashing at all is better than poor flashing. Improper flashing materials may be destroyed by corrosion or damaged by movement of a structure. Even good materials may be improperly installed. The result is that instead of excluding or controlling moisture, defective flashings tend to collect it in a manner to cause serious structural damage.

The vulnerable points of a masonry structure where flashing is recommended are at the grade line, the sills and heads of wall openings, where horizontal and vertical surfaces intersect, around spandrels, and at parapets.

Flashings are usually formed of sheet metal or bituminous membrane materials. Tin and galvanized iron may be used but they are

subject to quick corrosion and require frequent replacing and pointing. Lead also may be used. However, copper is the most preferred as it never deteriorates. Copper may stain light-colored masonry unless the copper is coated with lead.

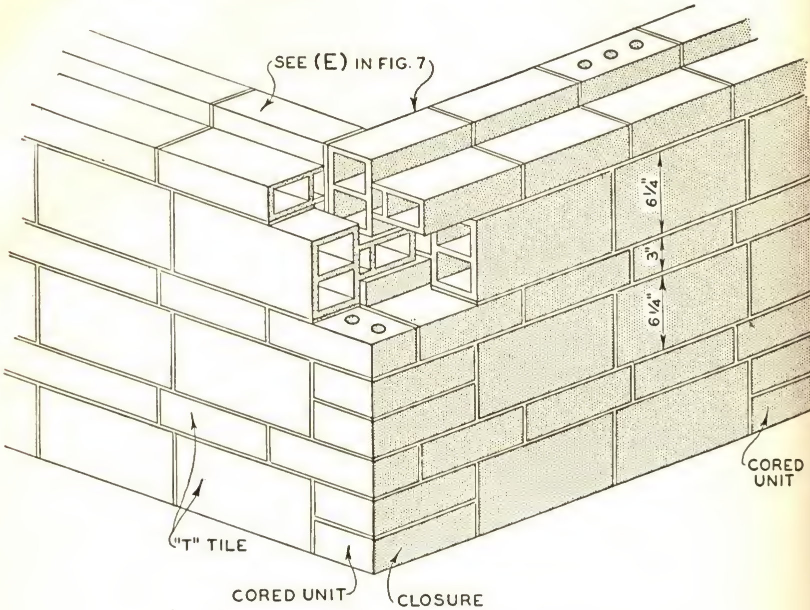


Fig. 19. Corner and Jamb Construction

Fig. 20 shows where the flashing should be installed in and around the various masonry details previously mentioned. Note that the flashings shown are all *through* flashings. In other words, they protect the entire interior of the walls, intersections, etc.

Fig. 21 shows where flashing should be used in typical cavity-type masonry walls. It will be noted that flashing is installed over all openings to deflect moisture outward toward the exterior wythes. Weep holes constructed in the exterior wythes at the bottom of cavities permit easy drainage of any water which may have entered the cavities. The weep holes are located in the vertical joints of the bottom course and can be spaced 2′0″ apart. They are easily formed with ⅜″ oiled steel rods or short lengths of rubber hose which may be withdrawn after mortar has set.

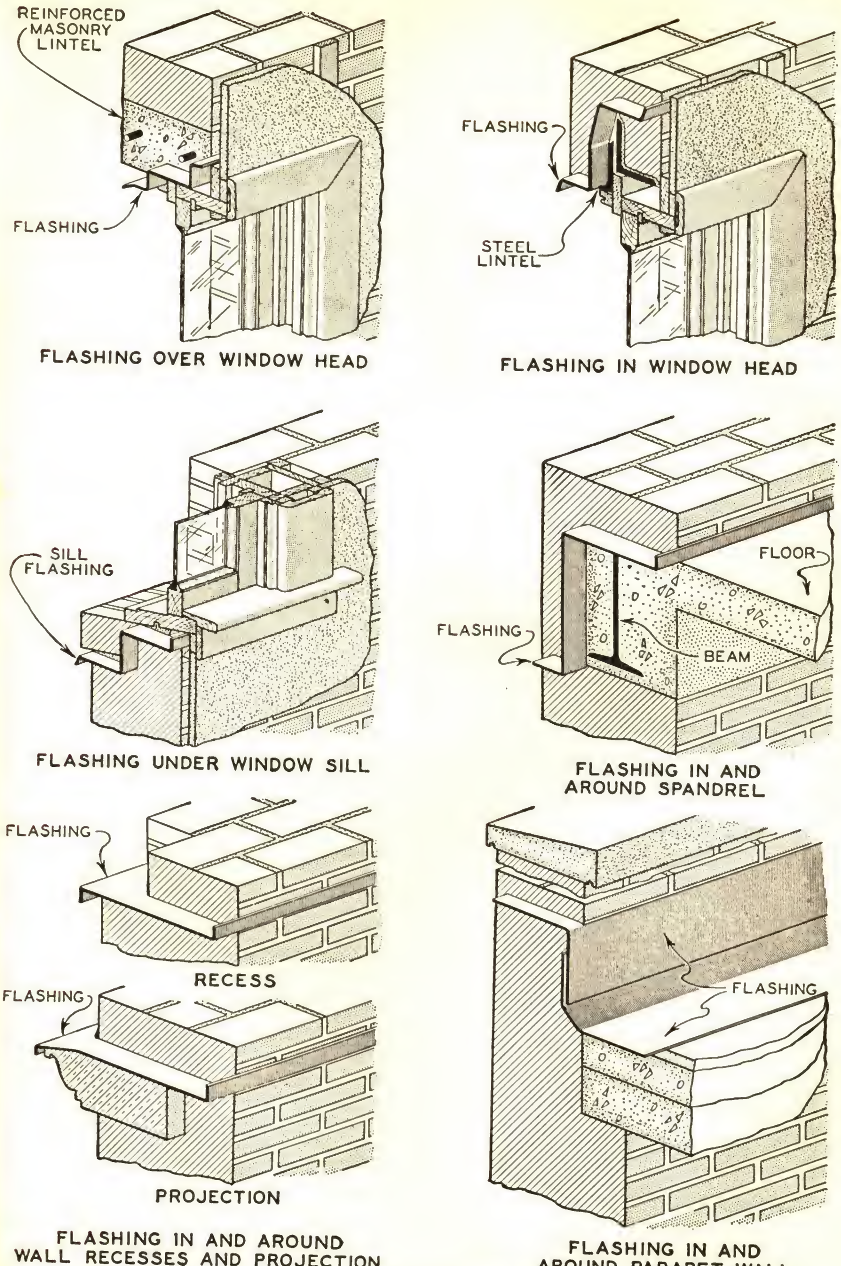


Fig. 20. Typical Flashing

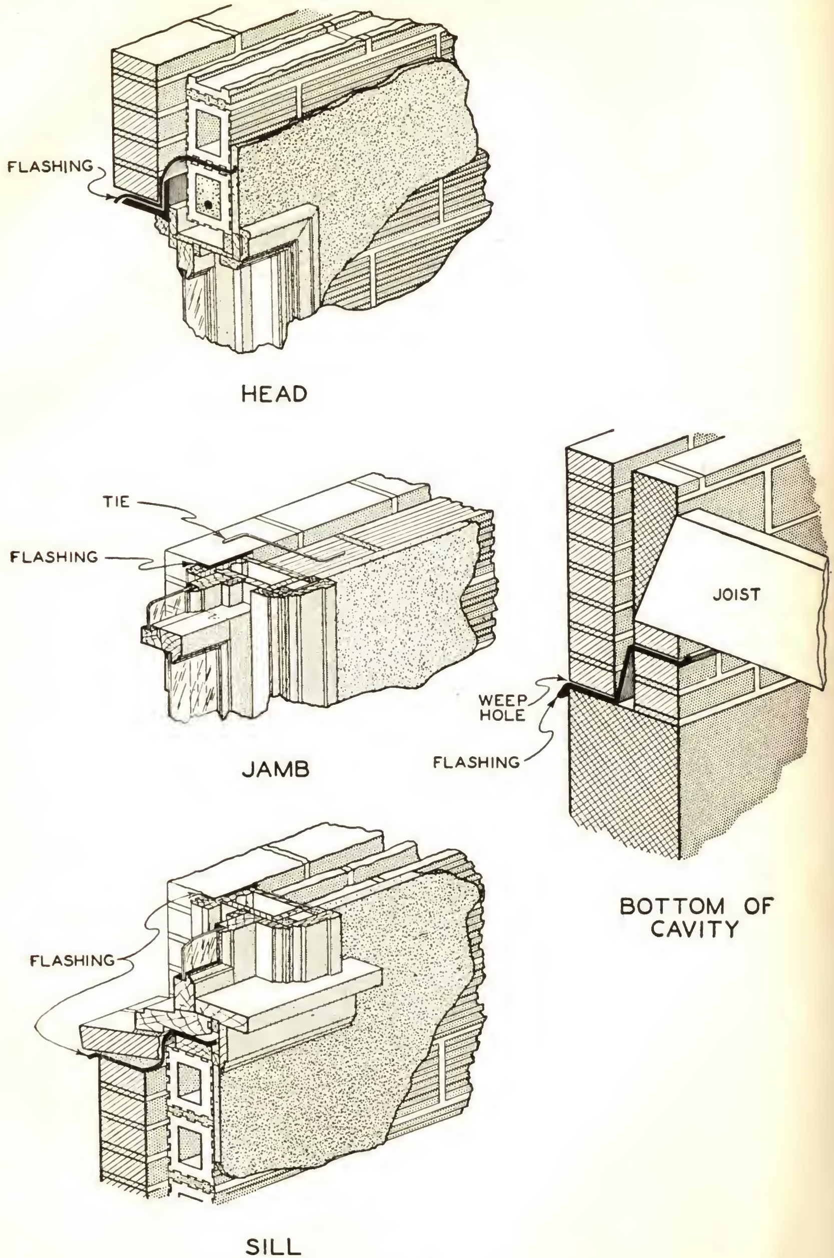


Fig. 21. Flashing for Cavity Walls

Metal Ties. Metal ties are used to tie or bond the two separate wall sections together in cavity-type walls. Some of the typical metal ties used in cavity walls are shown in Fig. 22. They should be made of steel and coated with a Portland cement grout. Galvanizing or zinc coatings are not considered permanent because of the actions of free lime which may be present in the mortar. The bars should be approximately ¼″ in diameter and bent so as to provide a hook of not less than 2″ in length for embedment in the horizontal mortar joints. The bars should be bent at right angles so that the hooks will run parallel to the wall sections. The **Z** bar is preferred although the rectangular tie is also satisfactory. The bars should be placed in every sixth or seventh mortar joint and spaced 24″ on center horizontally. Mortar should be spread on each wall section before the rods are embedded as this provides proper sealing between the rods and the tile or other masonry units.

Lintels. No discussion need be given here beyond calling attention to Fig. 23 where a typical reinforced tile lintel is illustrated as part of an 8″ solid tile wall. For ordinary window and door openings, the jambs on both sides of the openings can be made using ordinary closures and jamb units. However, where very wide openings occur, the lintels carry heavy loads and in such cases the jamb should be made of units such as shown at (B) in Fig. 8. These units, being practically solid, are stronger and make a much stronger jamb.

Practically any regular tile unit can be used to make lintels. In Fig. 23, closure units are used. In other cases whole jamb and large units are used. The stretcher unit in Fig. 23 could be used for lintels although units having smaller shells are not as good as units having larger shells because of the difficulty of getting the rods and concrete in place.

Pilasters. Enlarged wall sections or pilasters are required at points in walls where beam ends are supported. Beams generally carry rather heavy loads which an ordinary tile wall, without added strength, could not support safely. A typical means of making tile pilasters for solid tile walls is indicated in Fig. 24. Note that practically solid units, such as shown at (B) in Fig. 8, are used. The (A) and (B) courses are alternated in laying up the wall and pilaster to provide good bond. It can be seen that the pilaster does not in any way alter the pattern of the wall from the standpoint of exterior appearance.

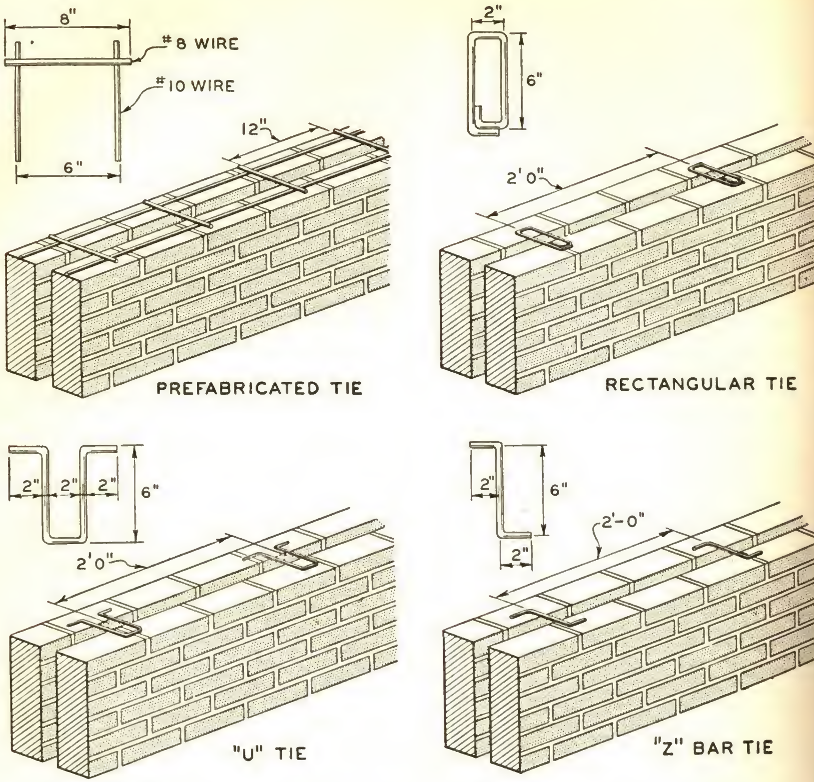


Fig. 22. Typical Metal Ties in Cavity Walls

Also shown in Fig. 24 is a typical pilaster of the type commonly used in cavity walls. Such pilasters can be much larger by simply adding to the number of extra units in both of the (A) and (B) alternating courses. The exterior wythe should not be connected in any way to the pilaster other than by the metal ties between wythes.

Partition Foundations. When a partition must be supported by a tile floor such as shown in Fig. 11, there must be a solid concrete foundation under it, as indicated in Fig. 25. The concrete foundation (really a footing) is required because the tile, with only a 2″ concrete covering, might not be strong enough to bear the weight. It is always best to make such partition foundations even if light nonload-bearing partitions are involved.

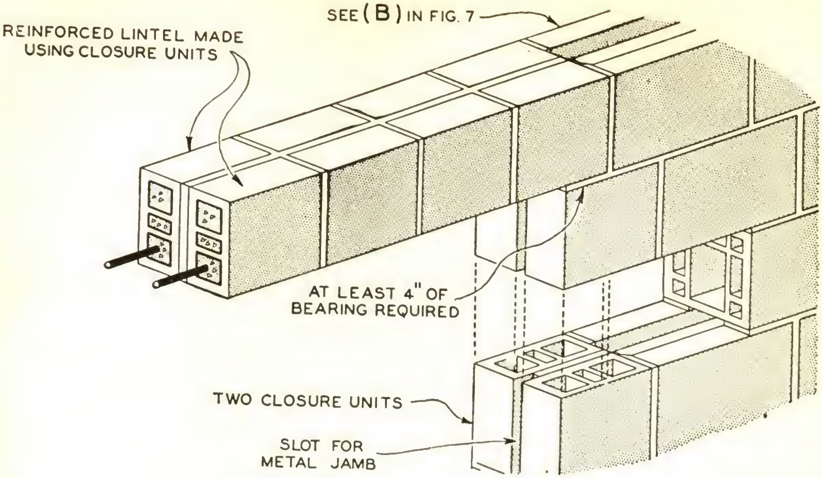


Fig. 23. Lintel in Typical Tile Wall

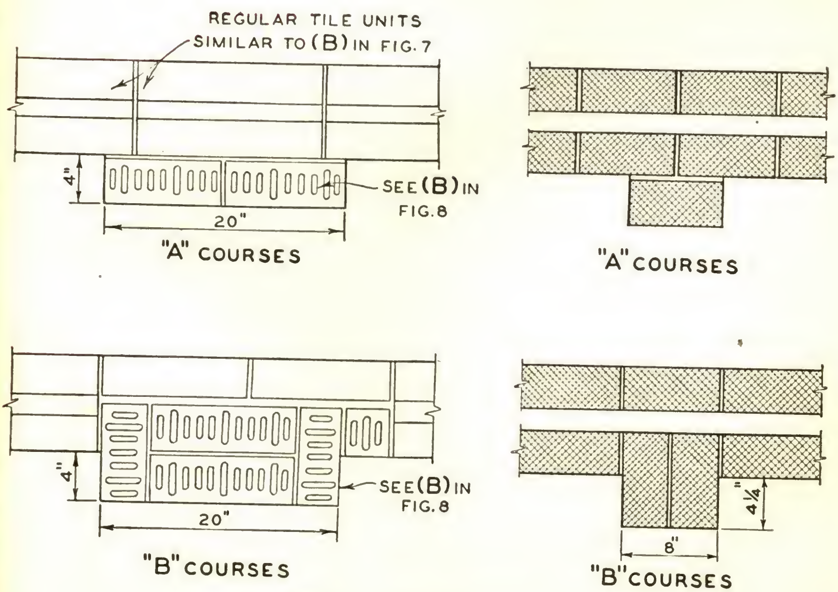


Fig. 24. Typical Pilasters

Nailing Strips. As for all masonry walls, nailing strips must be provided with tile walls wherever another structural part must be nailed to the wall. For example, consider the baseboards (sometimes called mopboards) which extend around a room at the floor level and are attached to the walls. Provision must be made whereby that moulding can be nailed to the wall without disturbing the plaster.

Generally two pieces of 1 x 2, called plaster grounds, are secured to the wall as shown in Fig. 26. They run parallel to each other and may be spaced from 2″ to 3″ apart. These grounds are in turn held in place

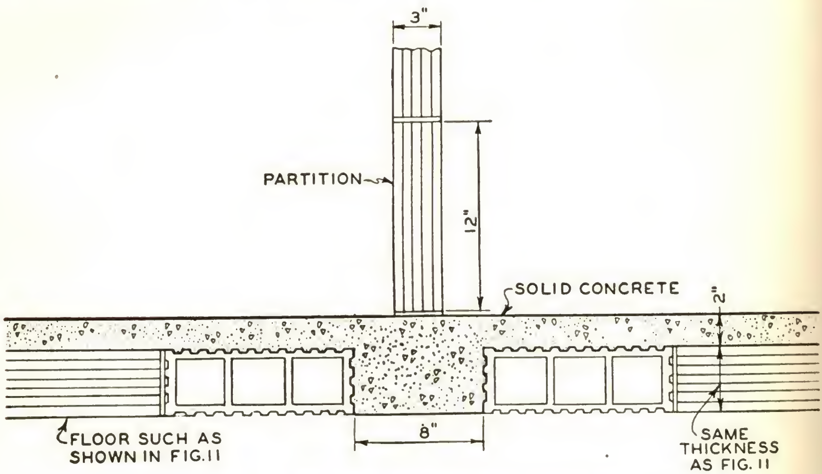


Fig. 25. Partition Foundation in Tile Floor

by 1 x 2 nailing strips, shown in Fig. 26, placed in a vertical position in the wall at about 16″ centers. These strips may be inserted in mortar joints or placed within cells and the cells filled with mortar so as to hold them in place. The grounds are nailed to the strips.

When the wall is finished, the plasterers apply plaster between and around the grounds so that the exterior surfaces of the grounds are flush with the plaster surface. Then baseboards are nailed directly to the grounds without cracking or harming the plaster. (See Fig. 27 for another view of the grounds and baseboard in place.)

Wall Draining. Efforts are being made continually to keep solid tile walls dry. Fig. 27 shows one typical method of laying units of special design to accomplish the purpose. The tile units used are similar

to the unit shown at (B) in Fig. 7 except that they do not have as many cells and the middle webs are sloped toward the exterior face of the wall. In this position, they act as a moisture drip. The water runs to the gutters of each unit in all courses and then down through the open joints between the lower shells from course to course. For instance, water in course *D* drips down to course *C*, from course *C* to

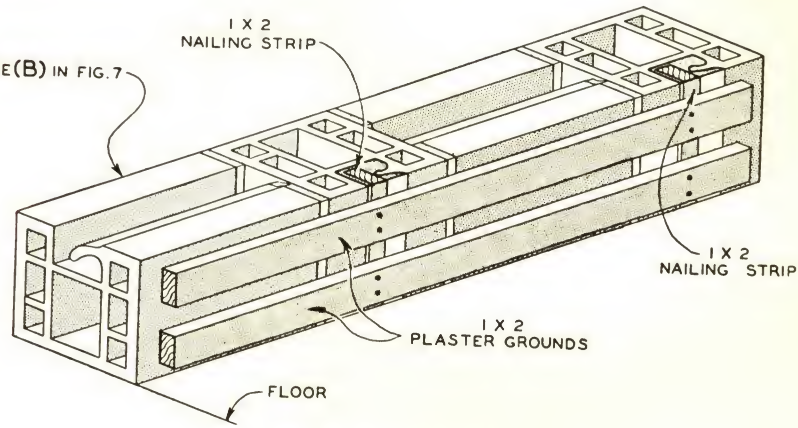


Fig. 26. Nailing Strips

course *B*, etc. All water finally accumulates at *X* in the first or lower course and runs out of the wall through weep holes spaced every 2 or 3 feet.

Tile Beam Floors. Tile beams, such as shown in Fig. 14, are used in connection with floors such as illustrated in Fig. 28. Special units called book tile are used between beams to support the concrete floor. These floors are strong but should not be used where heavy floor loads are expected without the advice of an architect or structural engineer.

Parapet Walls. Fig. 29 shows a common type parapet wall faced with brick and backed with tile units. Note that the cap slopes toward the roof so that water will be deflected to the roof and not down the front of the building. Flashing should be installed similar to that shown in Fig. 20. Of particular interest relative to the flashing is the flashing block where the flashing can be curled and held in place by mortar. Note that the handle of the tile locks the mortar firmly in place. Standard flashing blocks for use in parapet walls can be purchased for use in

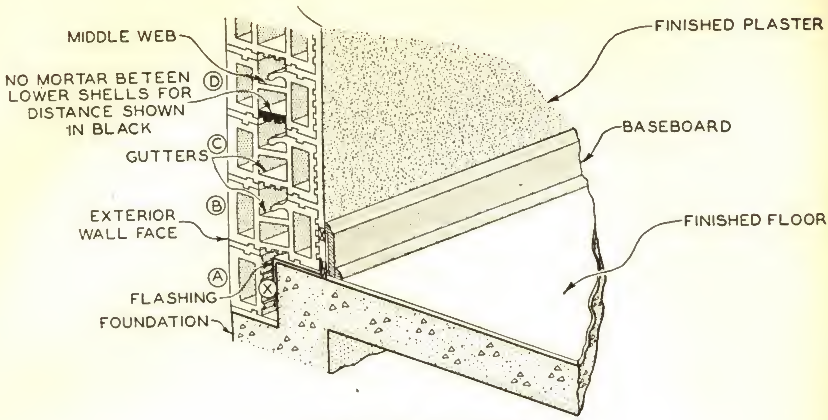


Fig. 27. Wall Draining

the event the tile units being used do not provide for such construction as shown in Fig. 29.

Cornice Construction. Fig. 30 shows several typical cornice construction details. The detail shown at (A) is for a cavity wall having a brick facing wythe and a tile backing wythe. Bricks are placed as a cap over the wall. Note that the top course for the tile wythe is also brick. A wood plate is laid over the brick caps. It is necessary to drill holes in the wood plate for the anchor bolt but not in the brick cap

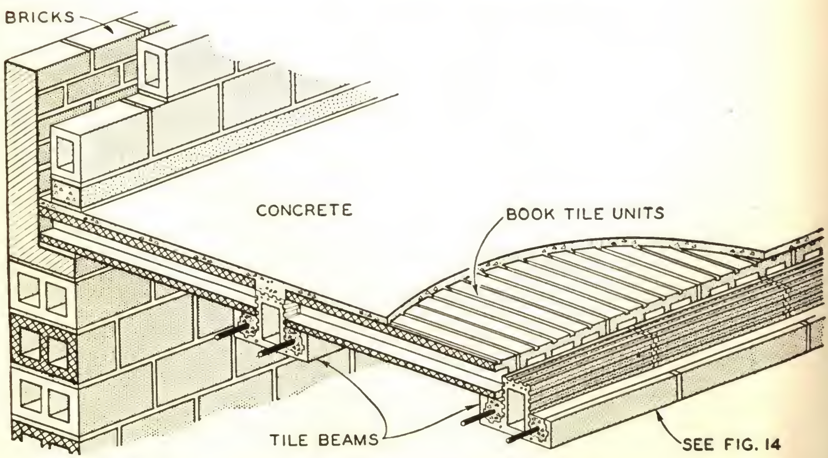


Fig. 28. Floor Using Precast Tile Beams

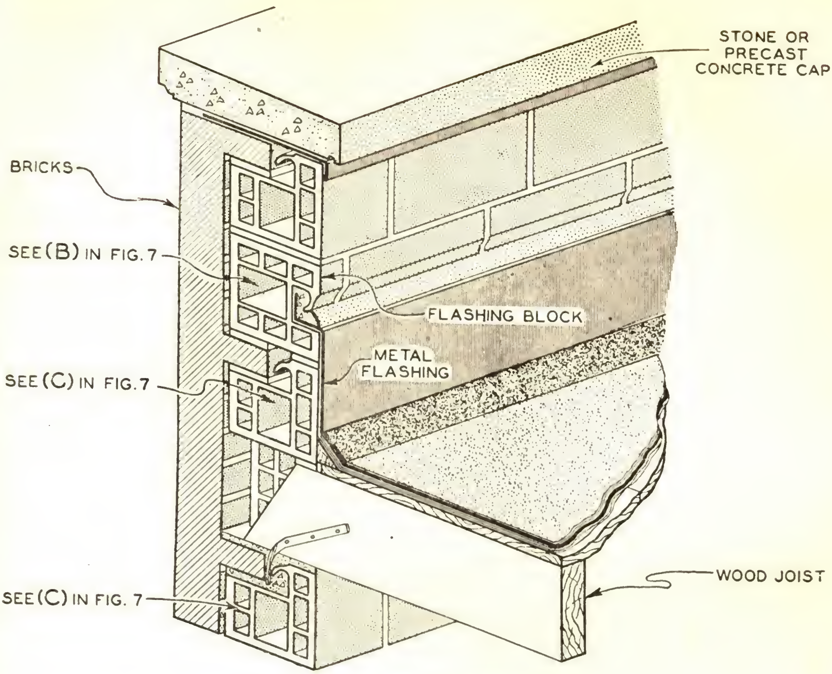


Fig. 29. Brick and Tile Parapet Wall

because the bolts can go down in the mortar joints between the bricks. These anchors should be spaced about 8′ 0″ apart.

The detail shown at (B) illustrates how wood plates are secured by anchor bolts in solid and cavity all-tile walls. The detail at (C) shows how the wood plate is anchored to a solid tile wall which also supports a concrete floor. The detail at (D) illustrates the anchoring of a wood plate in a tile cavity wall.

Anchor bolts must be carefully installed or their value will not merit their cost. They should fit snugly and their nuts be turned down tightly.

FIREPROOFING. The use of structural clay tile as a fireproofing material has been discussed on a preceding page. Fig. 31 shows two other typical examples of a channel beam and an **I** Beam (or column) properly fireproofed. Some of the structural advantages enjoyed by tile with regard to fireproofing are that it is much lighter than concrete, is quicker and easier to apply, and requires no forms.

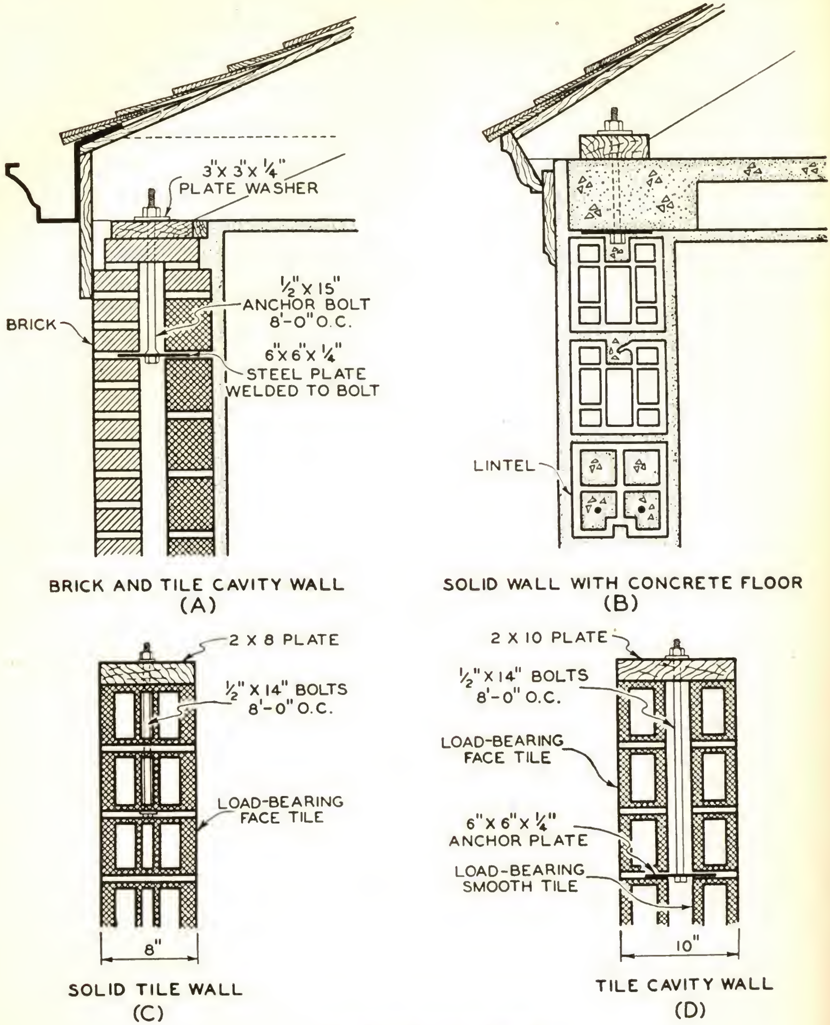


Fig. 30. Cornice Details

The channel beam, shown in Fig. 31, is partially fireproofed on the assumption that its upper flange will be covered with fireproof flooring or other masonry material. The **I** beam is properly fireproofed on the assumption that it will not be part of a floor or other masonry construction.

Generally, when covering beams with tile, the units should be

placed so that their cells run horizontally. When covering columns, the cells should run vertically.

Many special unit shapes can be obtained to make the exterior of column coverings circular or so the coverings have rounded exterior corners.

TERMITE SHIELDS. It was believed originally that termites inhabited only the southern part of the United States but experience has shown they exist as far north as the state of Minnesota.

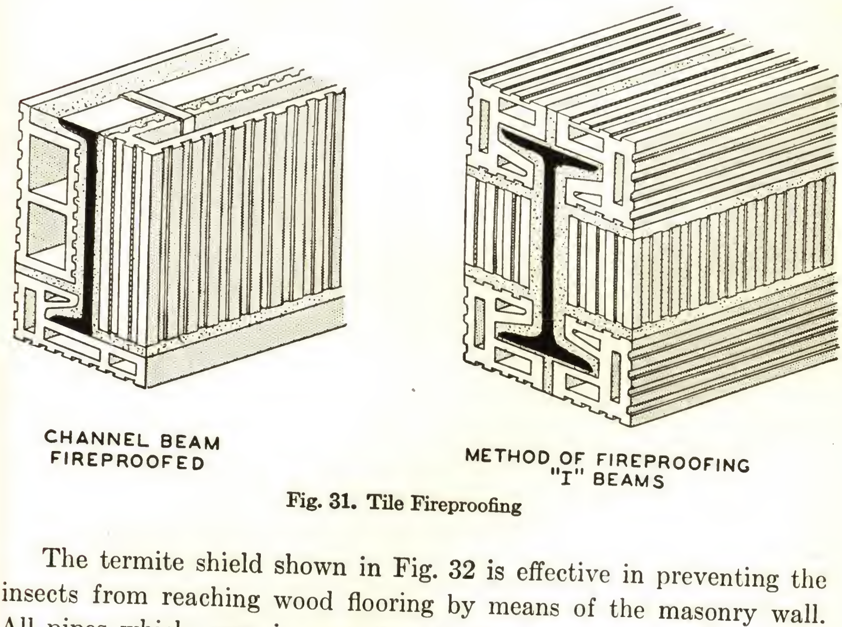


Fig. 31. Tile Fireproofing

The termite shield shown in Fig. 32 is effective in preventing the insects from reaching wood flooring by means of the masonry wall. All pipes which come in contact with wood structural parts and the ground should have a shield running around them which would force termites to walk upside down in getting around the shield. Since they will not do this, such shields are entirely effective.

LATERAL SUPPORT. Walls of solid structural clay tile should be supported at right angles to the wall face at intervals not exceeding eighteen times their thickness. Cavity walls should be supported at right angles to the wall face at intervals of not more than 16 times the wall thickness exclusive of the cavity. Such lateral support may be obtained by cross walls or pilasters when the limiting distance is measured hori-

zontally, or by floors and roofs when the limiting distance is measured vertically. This rule must be followed if safe walls are desired.

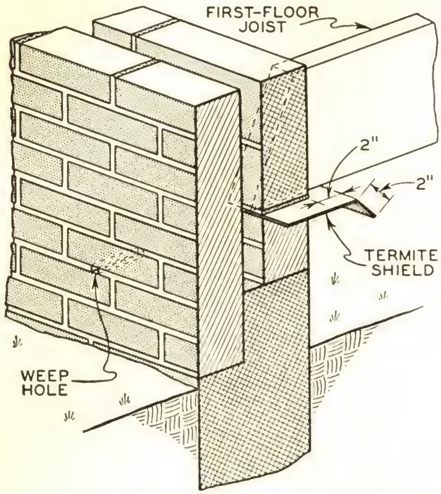


Fig. 32. Termite Shield

The recommended safe heights for structural clay tile partitions can be calculated approximately by multiplying the thickness by 40.

Table VI. Safe Heights for Structural Clay Tile Partitions

Partition Thickness in Inches	Maximum Safe Height in Feet
3	10
4	15
5	17
6	20
8	27
10	34
12	40

For any partition without support from cross walls or piers, the length should not exceed the safe height. A partition is considered supported if it has full-height door bucks or is between a masonry floor and ceiling.

Door Bucks. All door bucks should be securely anchored to partitions with metal strap anchors as shown in Fig. 33. These anchors

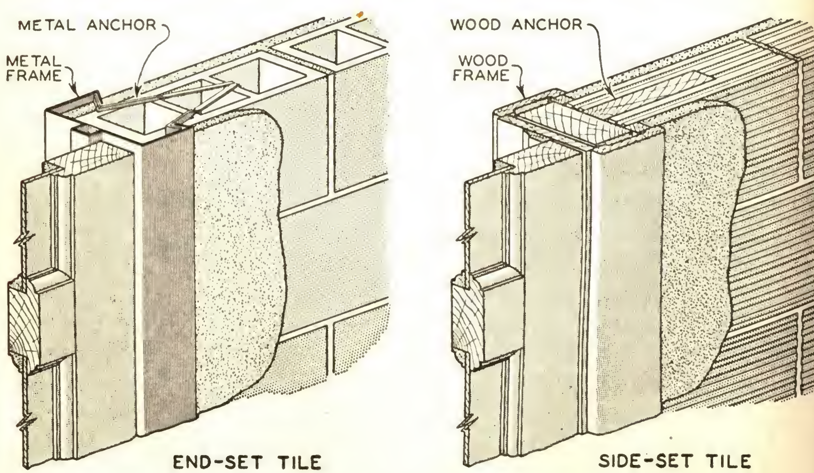


Fig. 33. Door Bucks

should be well embedded in the horizontal mortar joints of the tile to prevent their pulling out. Use end-construction tile with metal door bucks and completely fill all space between the buck and the tile with mortar. Use side-construction with wooden bucks in order to secure a more solid anchorage for the strap anchor.

WINDOW DETAILS. Figs. 34 and 35 show typical details for windows in cavity and solid tile walls. The windows in (A) and (B) of Fig. 34 show details relative to both wood and steel frames in cavity and solid tile walls. Those in (A) of Fig. 35 show wood and steel frames in stucco solid tile walls. The window details in (B) of Fig. 35 are typical of the kind used in poultry and other farm buildings.

DOOR DETAILS. Door details for tile walls are greatly similar to the door details explained relative to block walls in the chapter on concrete masonry. A few more typical details are shown in Fig. 36.

LAYING TILE

Once typical examples of tile units and their uses are known and typical construction details are understood and can be visualized, the actual laying of such units is not difficult and becomes largely a matter of experience insofar as skill is concerned. The following examples are simple but represent the sort of jobs frequently required.

Laying Tile Walls. For this example, the milkhouse end wall shown in Figs. 15, 16, and 17 will be used. It is assumed that concrete foundations are already in place, ready for the tile walls.

The first step is to set units, without mortar, around the foundation as was explained for laying blocks in the chapter on concrete masonry. Place the corner closures first, then the stretchers between corners. Calculate the vertical joint thickness explained in the chapter just referred to.

The horizontal mortar joint thickness for any wall can be determined if the height of the wall and size of units to be used is known. For instance, suppose a given wall height is 11′ 0″ and that units 5″ high are to be used. Try using a ½″ joint. Each course, when thought of as one unit and one joint high, would constitute 5½″ of height. The 11′ 0″ is the same as 132 inches. Dividing 132 by 5½ gives 24 which is the number of courses. Thus, the ½″ joint works out exactly.

The second step in laying a tile wall consists of laying about three

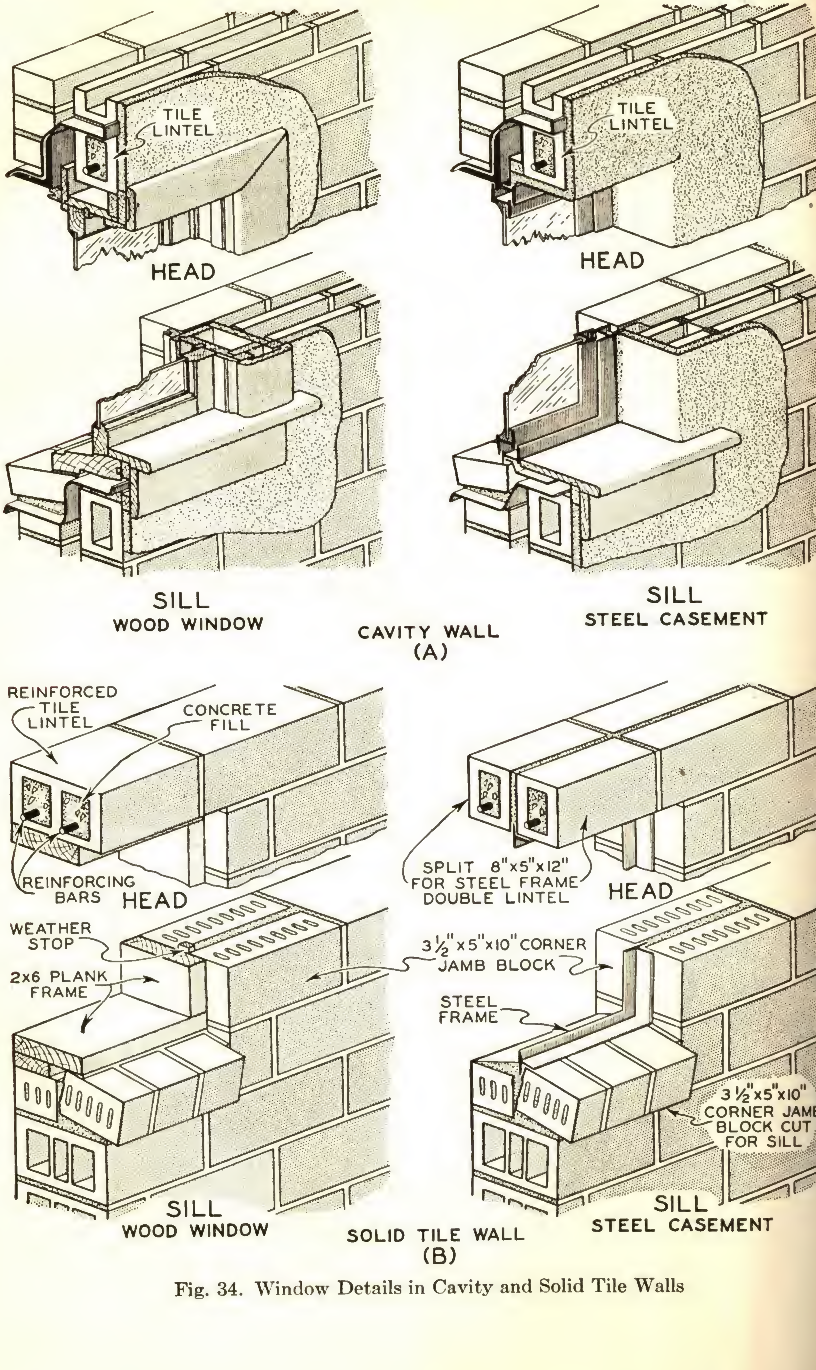


Fig. 34. Window Details in Cavity and Solid Tile Walls

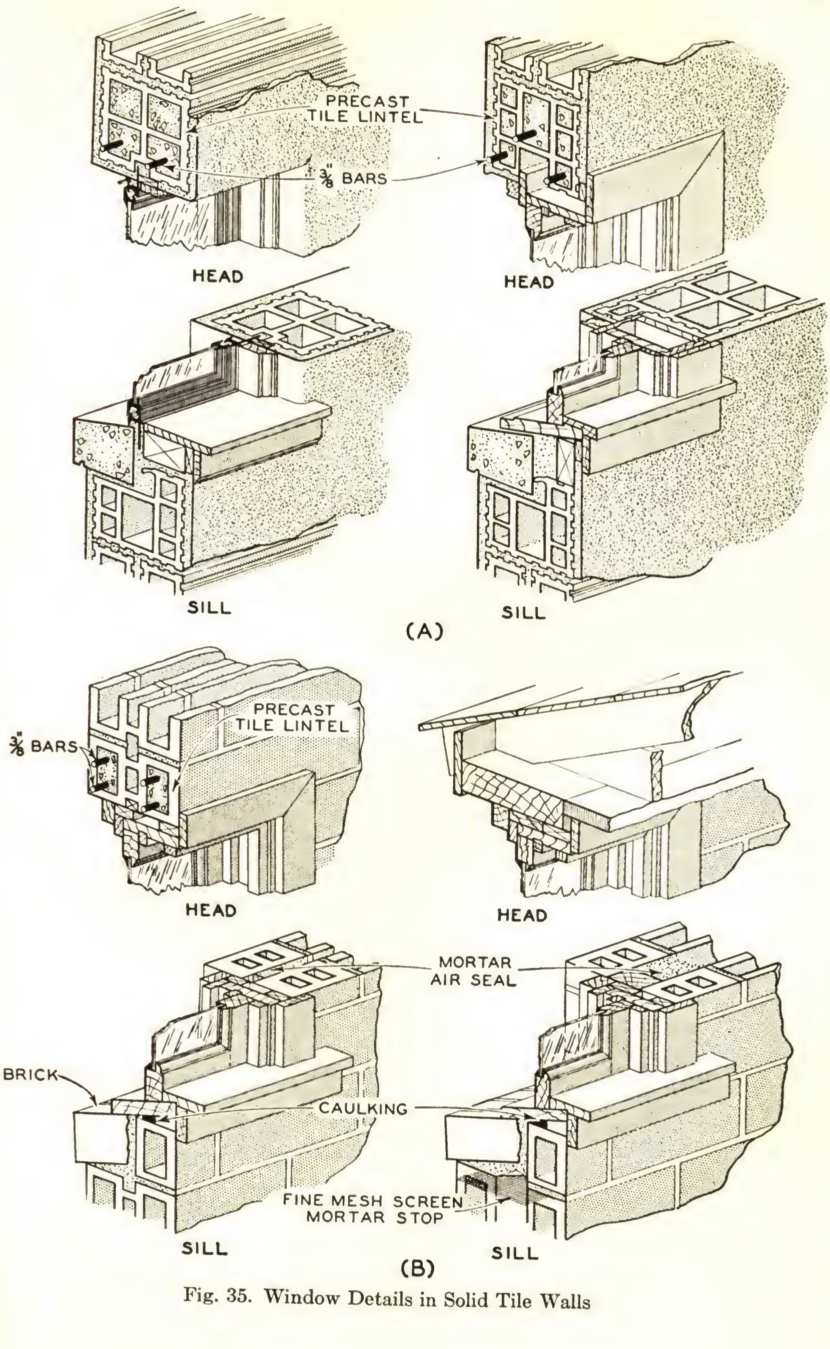


Fig. 35. Window Details in Solid Tile Walls

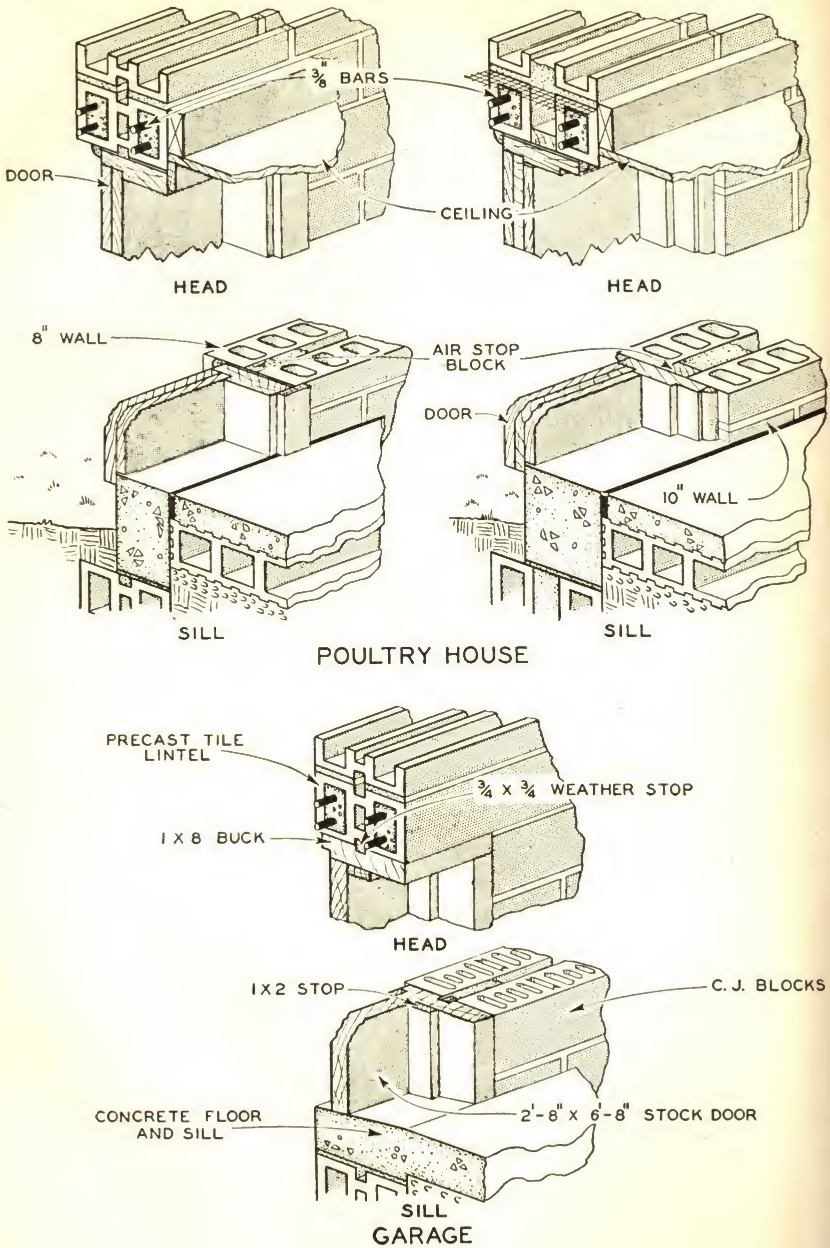


Fig. 36. Door Details

courses of units at two corners along the same wall as was explained in the chapter on concrete masonry.

Before units are laid, they should be dipped in water. This practice prevents their soaking up water from the mortar, thus injuring it. The surfaces of units which already have been set also should be wetted before applying mortar to them for the same reason.

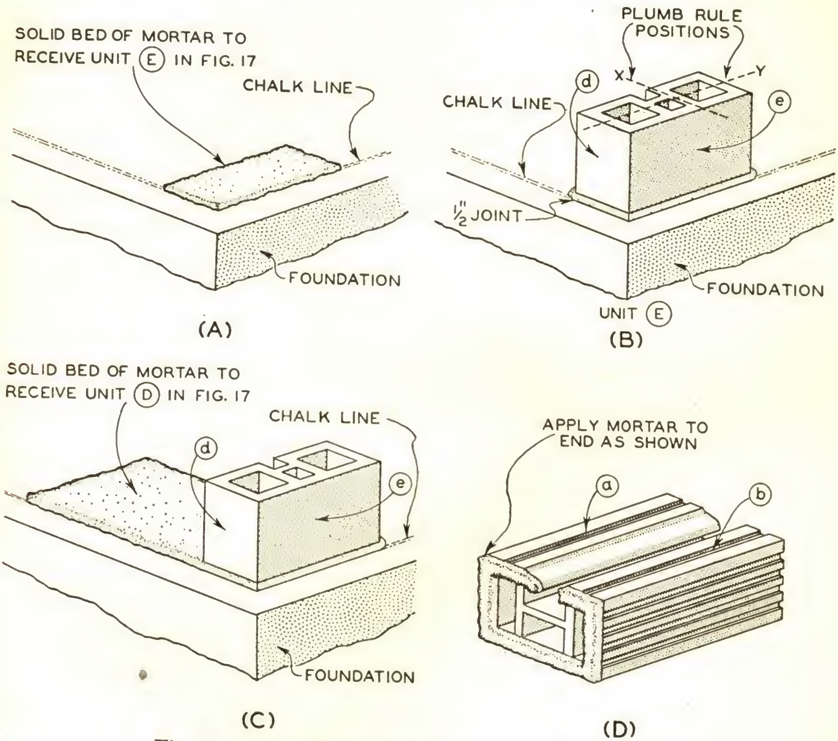


Fig. 37. Proper Mortar Bed at Corner for First Course

To lay unit *E* in Fig. 17, apply mortar to the top of the foundation as shown in (A) of Fig. 37. Lay the unit carefully down on the mortar, as shown in (B) of Fig. 37, and make sure that faces *d* and *e* are directly over the chalk line. The unit can be pushed downward by hand, by the trowel handle, or by using a hammer handle until the joint is ½″ thick. The excess mortar can be removed with the trowel, taking care not to remove mortar beyond the point of its being flush with the side of the block. Then place the plumb rule (level) in the positions

shown by lines x and y. If out of plumb, the unit can be pushed down until it is plumb in both directions, taking care not to reduce the joint thickness to less than ½ inch.

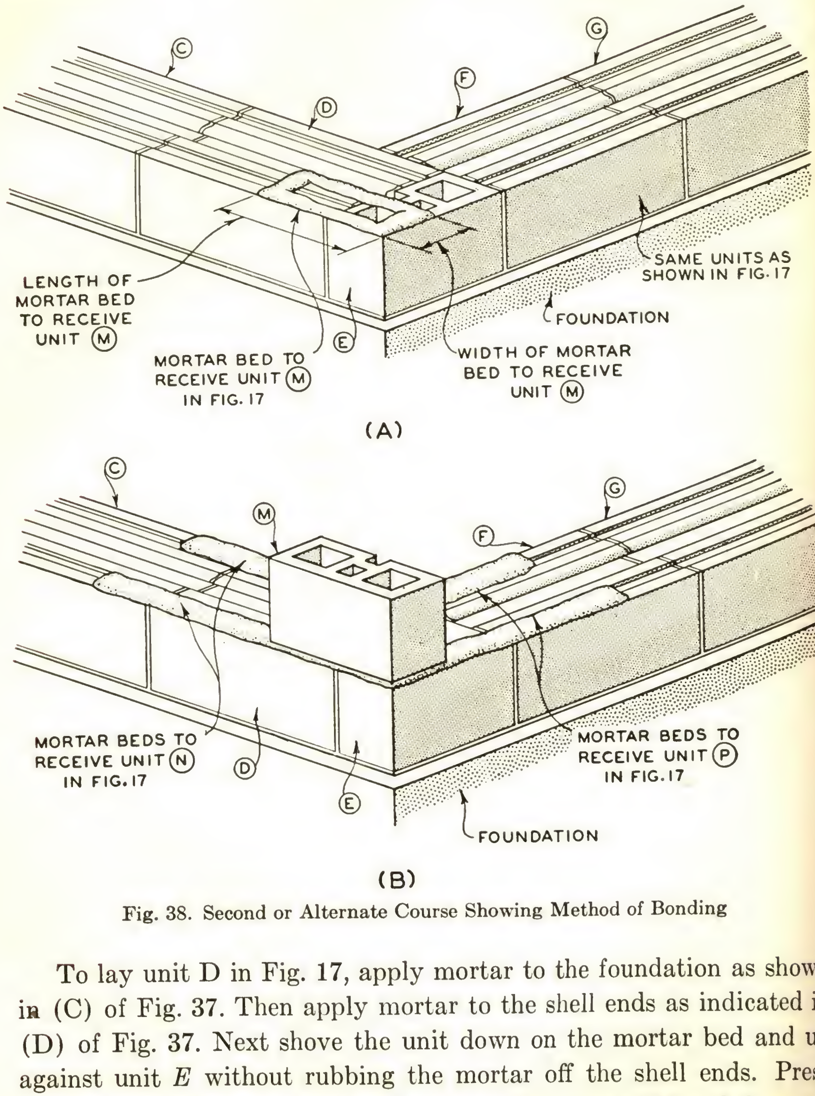


Fig. 38. Second or Alternate Course Showing Method of Bonding

To lay unit D in Fig. 17, apply mortar to the foundation as shown in (C) of Fig. 37. Then apply mortar to the shell ends as indicated in (D) of Fig. 37. Next shove the unit down on the mortar bed and up against unit E without rubbing the mortar off the shell ends. Press the unit carefully so as not to disturb unit E, toward E and down on the foundation until the ½″ mortar joints have been made. Be sure

the exterior face is just above the chalk line and test with the plumb rule.

Lay units *F, C,* and *G* in the same manner.

The next step is to lay the unit shown as *M* in Fig. 17. Apply mortar on top of units *D* and *E* as indicated in (A) of Fig. 38. Then set unit *M* in place as explained for the other units and as shown in (B) of Fig. 38. Units *N* and *P*, shown in Fig. 17, are laid next on the mortar beds shown in (B) of Fig. 38, following the same procedures as explained for unit *D*. Unit *R*, shown in Fig. 17, is set following the procedure explained for unit *M*.

A corner at the other end of the wall shown in Fig. 17 is next laid, following the same methods just described.

When both corners have been set, stretch a cord and proceed with laying the first course as explained in the chapter on concrete masonry. For the first course, the mortar bed must be the full width of the units. For the second and all other courses, two narrow mortar beds are required, equal in width to *a* and *b* in the sketch in (D) of Fig. 37. The units should be set following the procedures already explained relative to units *E, D, F, M,* etc.

In all cases where one unit is joined to another, as explained for unit *D*, the ends of the unit being laid should have mortar applied to the outer shell all the way around.

When one wall is complete to the extent of three courses, the other three walls can be completed up to three courses in like manner. Then, to continue laying the walls, build up two corners of one wall three or four courses deep and lay the courses as before, etc.

Laying Veneered and Cavity Walls. In veneer or cavity walls, the wythes are laid separately. The exterior wythe is usually laid up first to a height where the first anchors (see Fig. 22) are required. The corners are erected and trued with the plumb rule and the corners then built up using the nail and cord procedure as described for tile and concrete masonry walls. The interior wythe can be laid up to the same height, the anchors installed, and the whole process repeated until the wall is completed.

When veneering is bonded into the backing, the corner and cord procedure is followed, but the complete wall thickness is laid as the height progresses. The double pointing explanation previously given

should be kept in mind. Fig. 39 indicates typical mortar requirements.

Laying Partitions. The procedure for laying partitions is generally the same as for walls and as explained in the chapter on concrete masonry for block partitions. If a tile partition is being laid from one wall

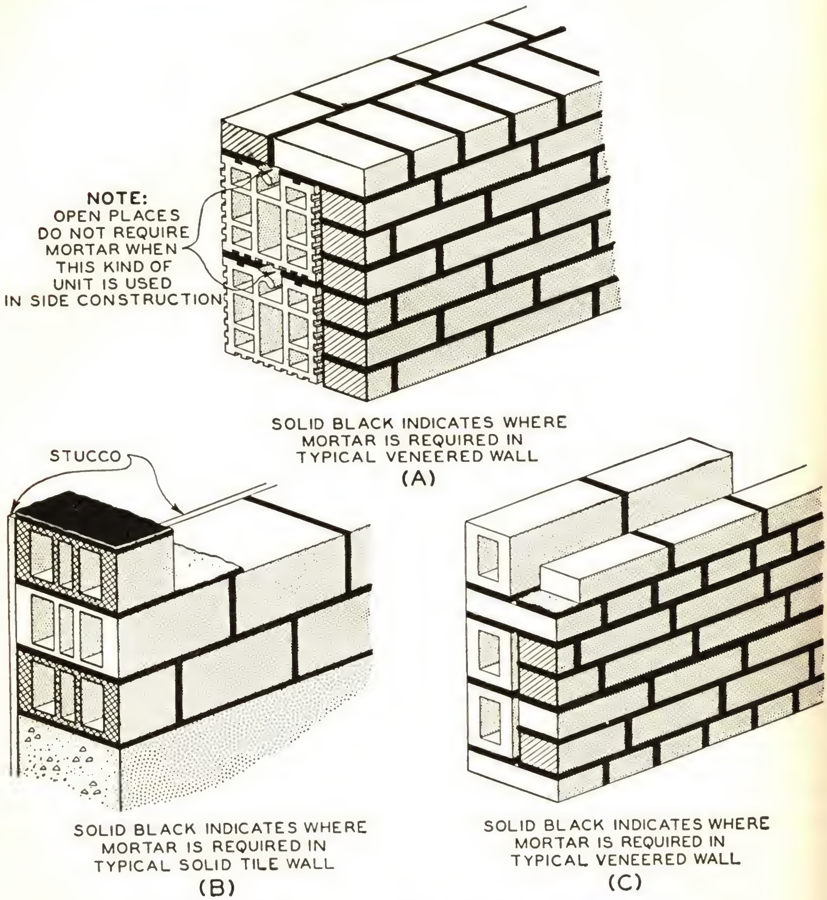


Fig. 39. Typical Mortar Requirements

to another and has no corners, the two ends are built up for three or four courses as explained for corners, the intervening stretchers laid, etc.

When laying either walls or partitions, the joints should be carefully pointed just as the mortar starts to set. This can be done in much the same manner as explained for concrete blocks.

Laying Units Around Windows. This procedure is practically the same as explained in the chapter on concrete masonry. The only difference is that tile units are generally smaller and must be set more carefully.

In Fig. 17, the window opening is surrounded at the jambs by three different types of units, all of which must be set carefully and according to a prearranged plan. The inexperienced mason always should draw a plan similar to Fig. 17, or (B) of Fig. 34, before starting to lay a wall. Such plans should be drawn to scale so that the style and position of each unit, including sills and lintels, is definitely known. Without such a plan, an inexperienced mason is almost certain to encounter serious difficulties if not complete failure.

The mortar used in laying units should be kept wet enough so that it can be worked easily and so that it is not stiff at the time of application. On the other hand, mortar should not contain so much water that it will not stick to the edges of shells as various units are "buttered" for laying.

The inexperienced mason should not apply mortar beds for horizontal joints in advance of more than one unit. This practice will assure good setting and prevent beds being partially set before units are set into place.

Laying Units around Door Openings. This procedure closely follows that for laying units around windows and is explained in the chapter on concrete masonry.

Side and End Construction. The application of mortar for both side- and end-construction work is highly important from the standpoints of strength and of keeping the construction as nearly waterproof as possible. The waterproofing standpoint is of the greatest importance in exterior walls where no surfacing such as stucco is to be applied. The following suggestions best can be understood by studying Fig. 1.

END CONSTRUCTION. For end-construction work, all vertical joints, such as *A* and *C*, should be *full* of mortar. Before each unit is set into place, mortar should be applied to the sides, such as *E*, in such a manner that the whole side is covered. Or, some mortar may be applied to the end of the unit already in place so that the unit being set can be shoved up against it. Whichever way it is done does not matter, if the entire end surfaces are covered so the joints will be filled with mortar.

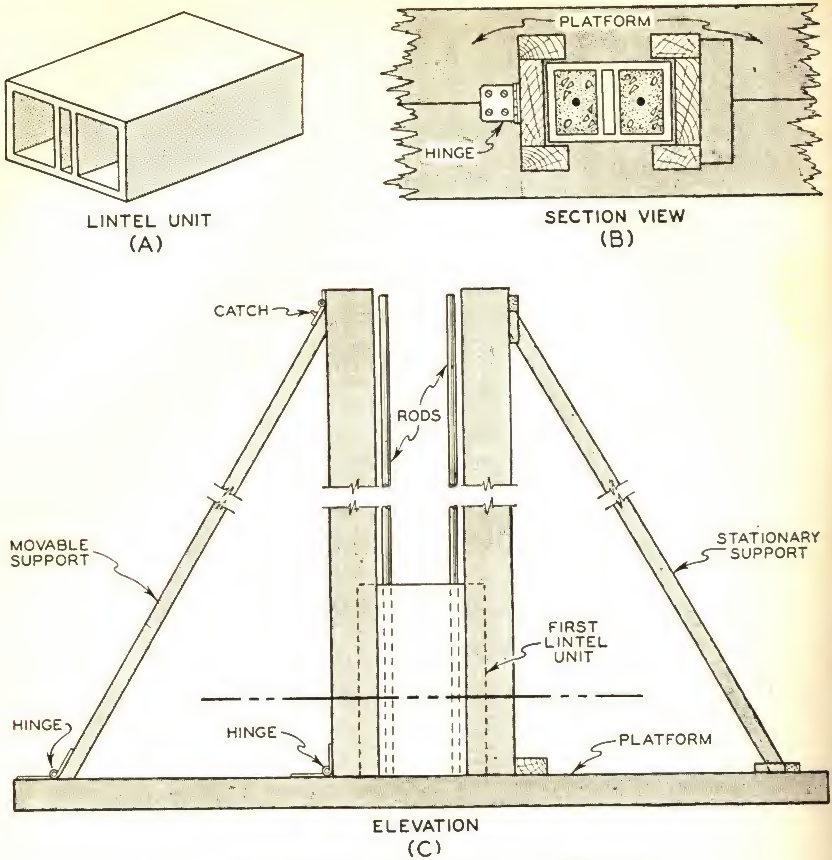


Fig. 40. Fixture for Making Reinforced Tile Lintels

The horizontal joints are equally as important. Before each unit is set into place, mortar should be applied to the shells of the units already in place. The main purpose is to have mortar under the shells.

Side Construction. For side-construction work, all vertical joints should have mortar as explained for the horizontal joints in end construction. (See also Fig. 39.) For the horizontal joints, the complete top surfaces (except as noted in (A) and (C) of Fig. 39) such as at (B) should be covered with mortar before each new unit is set into place.

Making Reinforced Lintels. As indicated in the various illustrations throughout this chapter, reinforced tile lintels can be made using any shape of unit.

Suppose that units such as (A) of Fig. 40 are to be used in making reinforced tile lintels. The sketches at (B) and (C) show a typical wooden fixture which would be helpful in making lintels. The fixture is placed on a wood platform. One side of the fixture and its support are hinged so they can be lowered when finished lintels are ready to be removed.

With such a fixture, the first unit can be put in position and the movable support locked in place. Half-inch rods (generally) which have been cut to the required length are then dropped into the two large cells in the unit. The cells are filled with concrete (see chapter on concrete) and tamped firmly into place. Mortar is then applied around the shell and the second unit slid down from the top of the fixture. It should be pressed down to make a good 3/8" to 1/2" mortar joint. Then its cells are filled with concrete. This process can be continued until the lintel is the required length. The lintel should not be removed from the fixture for at least two days in warm weather and a week in cold weather. If possible, the lintel should be covered with damp sand or earth and cured for seven days.

Making Tile Beams. Special tile units such as shown in Fig. 14 must be used in making beams. Some sort of a wooden fixture to hold the units in a straight line should be made. The fixture should be supported by planks or a platform. The units are laid with full 3/8" mortar joints between them. Care must be taken that all units are in perfect alignment.

Some engineers maintain the cavities should be filled with strong cement mortar. Others prefer concrete. Whatever is used, the cavities should be about half filled, after which the 1/2" steel rods can be placed. Then the filling of the cavities can be completed. Allow the beam to set for two days in warm weather or a week in cold weather before moving. If possible, such beams should be cured for seven days buried in damp sand or earth. The beams should be thirty days old before being placed in load-bearing situations.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. If unit shells are in a vertical or horizontal position in side-construction tile work?

Answer. They are in a horizontal position.

2. How many different sized units are possible in an ordinary utility unit?

Answer. Four different sizes are possible.

3. If units for concrete floors are in side- or end-construction position?

Answer. They are in side construction position.

4. Where sleepers are used?

Answer. In floors having a concrete base and a wood surface. (See Fig. 12.)

5. Where a skew tile unit is used?

Answer. In a segmental arch floor. (See Fig. 13.)

6. Where shoe units are used?

Answer. Same answer as for Question 5.

7. Where weep holes are used?

Answer. At the bottoms of walls, especially cavity walls.

8. How long ordinary Z bar wall ties are?

Answer. The total length of the rods is generally 8 inches.

9. If slotted jambs are used only for metal frame windows?

Answer. Sometimes a weather stop for a wood frame window may be inserted into them.

10. Where flashing blocks are used?

Answer. In parapet walls.

11. What the average weight is of scored tile having a nominal thickness of 8 inches?

Answer. Table 5 shows an average weight of 36 pounds per square foot.

12. How many cells an 8″x12″x12″ clay tile unit would be likely to have?

Answer. Table 4 shows 4.

13. Where the LB grade of structural tile can be used?

Answer. For all kinds of load-bearing walls which are not exposed to frost action.

14. How a tile unit should be designated if it were smooth on all four sides?

Answer. By the designation S-4-S.

15. When dimensions showing the over-all size of a tile unit are given, what the first of the three dimensions means?

Answer. The through-the-wall thickness.

16. In what direction the shells should run in units used to fireproof steel beams?

Answer. Vertically.

17. Why common structural clay tile units should be wetted before mortar is applied to them?

Answer. So they will not absorb water out of the mortar too rapidly.

REVIEW QUESTIONS

1. Why is side-construction considered best for ordinary tile walls and partitions?
2. Explain how mortar should be applied when side-construction tile work is being done.
3. What is the difference between shells and webs in common structural clay tile units?
4. Why are tile units scored?
5. What dimensions should be applied to tile scoring?
6. What is the difference between common and face tile units?
7. Why is it that regular patterns so far as joints are concerned, are not always possible in walls built of common structural tile units?
8. What is a closure unit and what is its purpose?
9. What is a utility unit and what is its purpose?
10. Why should inexperienced masons, especially, make careful drawings of tile walls before starting to lay them?
11. What are C. J. blocks and where are they sometimes used?
12. In what type of walls are wall anchors used, and what is their purpose?
13. Explain, by steps, the proper method of laying a tile wall.
14. Why isn't galvanized sheet metal the best material to use for flashing?
15. What is a so-called jumbo unit and what is it for?
16. What is meant when tile units are said to have cored shells?
17. Explain what a tile beam is, how it can be used, and how it is made.

CHAPTER VII

Brick Masonry

QUESTIONS CHAPTER VII WILL ANSWER FOR YOU

1. *How is brick manufactured and what are some of the materials used?*
2. *What are some of the more common types of brick and how are they used?*
3. *What are the tools used by the bricklayer and how should they be employed?*
4. *How should mortar joints be made correctly?*
5. *How are the bricks laid up in courses in some of the typical bonds?*

INTRODUCTION TO CHAPTER VII

Brick masonry or the use of bricks as a building material is the most interesting of the three types of masonry under consideration in this book because it, along with pottery and implement making, is one of the earliest manifestations of man's culture. It was one of the most important indications that he had risen above the savage, animal-like habits of his ancestors. Because masonry has been so closely associated with the cultural life of man—from a time dating back to the dawn of civilization—it is steeped in the tradition of history.

The coming of the mason and the development of masonry was a great event in the lives of early men. Today it is of great importance in our way of life yet it is scarcely given a thought by the millions of people whose existence is so greatly influenced by it.

Brick masonry is important to the inexperienced mason because it is the most difficult of the common mediums in which to work. The various bonds and wall pattern styles are numerous and each requires great skill and care. However, no other structural material offers the same scope either in the colors and textures available or the variety of wall patterns and bonds obtainable. No other material offers the same possibilities for the exhibition of skill and perfection in the field of masonry.

A careful study of this chapter will impress you with the heritage that rightfully belongs to masonry. You will learn the early history of brick. You will become acquainted with the various methods of brick manufacture following their complete processes through to the finished product. You will learn the kinds of brick and their applications. You will discover that brick size is an important factor to be considered in designing wall lengths and door and window locations just as it was in working with concrete blocks and clay tile. You will know the more common bonds in use in the United States and how to lay them. You will learn the difficult, important details involved in laying brick at corners, around doors and windows, and across lintels,

always maintaining the proper bond. You will find that there is a great deal more to corners than piling bricks one on top of the other. Because of the difficulty in properly bonding corners, great care has been taken to demonstrate adequately the correct method through carefully prepared illustrations and detailed descriptions. You will learn many other details connected with masonry too numerous to mention here. Finally, you will learn something of the technique necessary in laying pilasters, columns, and simple chimneys.

DEFINITION AND DESCRIPTION OF BRICK MASONRY

The term *brick masonry* should be applied only to that type of construction employing comparatively small building units made of burned clay or shale. There are bricks made of other materials but when such bricks are used in masonry work, the term brick masonry should not be employed. The standard physical properties for bricks used in brick masonry structural work are set forth by the United States Government and by the American Society for Testing Materials in what are known as *Federal* and *Standard Specifications* for brick masonry. These specifications are offered free of charge and are suggested for anyone interested in selecting and buying brick for use in masonry work.

Ordinary brick are economical in cost and when hard-burned and laid in good mortar are one of the most durable construction materials now in use. Bricks are comparatively small in size and are therefore easy to handle. Since they are thoroughly burned during their manufacture, they can be used in construction work intended to be fire-resistive as well as in other forms of construction that are intended to be absolutely permanent in character.

The purpose of this chapter is, first, to outline briefly the history of brick masonry; second, to explain the materials used and the processes involved in the manufacture of bricks; and third, to describe many principles and construction applications which young or inexperienced masons should understand. It should be made clear that the applications of brick masonry principles explained herein are only those which are commonly encountered in average brick masonry work.

EARLY HISTORY OF BRICK MASONRY

If aristocracy prides itself because of its ancient lineage and honorable service, then it may be claimed that bricks are an aristocratic building material. If strength and refinement came to men through

the experiences of trial and difficulty, the same distinction may be attributed to bricks.

The archeological excavator finds evidence that sun-dried (or adobe) bricks were used thousands of years before the earliest recorded date of history. The great antiquity of brickmaking is strikingly confirmed by the recent excavations at Ur, the native city of Abraham in Babylonia. Here was found brick masonry, of a kind, that was used 6,000 years ago. The quality of this brick masonry was found to be astonishingly good and very well preserved. By the time of the reign of the great Babylonian King, Nebuchadnezzar, about 604 to 561 B.C., men had acquired the art not only of making hard-burned bricks, but also of molding and enameling them. These ancient people highly prized the art of brickmaking and bricklaying. The kings took the industries under royal patronage and had their names stamped in the bricks produced by their people.

A Greek historian of the fifth century B.C. gives a glowing account of the wonders of Babylon, the most striking of which were the immense walls, temples, etc., all of which were constructed of bricks.

It was doubtless from the Mesopotamian plains that the art of brickmaking in ancient times spread eastward to Persia, India, and China, and westward to Egypt, Asia Minor, Greece, and Rome. The most ancient Chinese records reveal nothing on the use of bricks comparable to the antiquity of brickmaking in the lower Mesopotamian valley. It was there that the Sumerians, who are regarded as a Turanian people allied to the Chinese, developed the art which was adopted by their successors and which they carried with them as they were driven northeastward by the invading Semites. In other words, the art of brickmaking was introduced in the East by the displaced Sumarians and in the West by their conquerors.

Everyone is familiar with the Bible story of the Hebrew bondage in Egypt and how, after the days of Joseph, the Egyptian Pharaohs compelled the children of Israel to make bricks without furnishing them with the straw, which they had to procure for themselves, to use as a binder in mixing the clay (Ex. V, 7-19). But in Egypt, which (so far as the antiquity of its civilization is concerned) rivals Babylonia, the most ancient brick remains do not go further back than the fifteenth or sixteenth century B.C., as represented in the two brick pyramids of sun-dried bricks found at Dashur, a few miles south of Cairo.

Europe learned its practice in making and using bricks from the Romans, the great builders of antiquity who left splendid and extensive remains of brickwork in nearly every part of their wide domain. The Baths of Caracalla, the basilica of Constantine at Rome, and the remarkable dome of St. Sophia's at Byzantium, or Constantinople, are examples of the Roman brick-masonry art.

In England, from which our own brickbuilding practices have been derived chiefly, the first brick manufacturing was that of the Romans during their three-and-a-half centuries of occupancy. However, the native industry did not appear until the thirteenth century; and it was the period of Henry VIII (1509–1547) before English brickmaking was perfected, probably under Flemish influence. The great fire of 1666 transformed London from a wooden to a brick city and was a great spur to the brick industry. The days of Queen Anne and the Georges in the eighteenth century brought about a decided vogue which almost drove out all other kinds of building material and resulted in those fine old country houses so representative of substantial comfort and dignity, which are scattered throughout England.

America is not without its brick antiquities for the Spanish Conquistadors found excellent adobe brickwork in Peru and Mexico and further developed the art in their own settlements. In the North American colonies which naturally followed English practice, the first brick houses were built of material brought from England or Holland. The domestic industry can be traced to Virginia in 1611 and to Massachusetts as early as 1629.

MATERIALS USED IN BRICK MANUFACTURE

The raw materials in the form of clays or shales from which burned bricks are made are found in all parts of the country. Clays are produced naturally by the weathering of rocks. Shales are produced naturally in practically the same way and from the same material, but differ from clays in that the shale has been compressed, and, in some cases heated, producing a material that is much more dense than clay, and consequently more difficult to remove from banks or pits. The chemical composition of clay or shale and the method of firing them give the various colors and textures to bricks. The colors vary from a light cream to very dark red, with red, buff, and cream predominating.

BRICK MANUFACTURING

Clay and shale are dug or quarried and in some cases allowed to weather in the open for a period of time. The purpose of this weathering is to allow the material to break down naturally into a workable mass. Brick plants are usually located near the source of the raw material. Since the process of brick manufacturing is uninterrupted, the raw materials must be dug or quarried continuously so that delivery to the brick plant will be constant. If the clay or shale delivered to the plant contains the proper ingredients, it is a simple process to grind, mix, and mold the bricks preparatory to firing. However, it is necessary sometimes to mix two or more kinds of shale, clay, or other ingredients in order to produce a mixture of the proper consistency.

Methods of Molding Bricks. There are several methods of molding bricks. Among these are the stiff-mud,soft-mud,and dry-press processes. Each process requires slightly different molding equipment and treatment in mixing. The shale or clay must be ground and mixed to the proper consistency for molding and the correct amount of water added.

Stiff-Mud Process. In the stiff-mud process of forming and molding, the clay is delivered to an auger machine which forces the plastic mass through a die in a continuous stream called a column. The die molds the mass into the desired shape for brick and as the column is extruded, it passes through a machine which cuts it into the desired lengths.

Soft-Mud Process. In the soft-mud process, machines press the clay into forms rather than extrude it from a die. The final results are the same as in the stiff-mud process.

Dry-Press Process. The dry-press process permits the use of more or less nonplastic and relative dry clays. The clay is put into molds and subjected to pressure of from 550 to 1500 pounds per square inch.

Drying of the Molded Shapes. An important part of the manufacture of bricks is the drying of the molded shapes. It is necessary to evaporate a large amount of the water in the molded bricks to assure greater strength. The more thoroughly the bricks are dried, the easier it is to stack them properly in the kilns.

Molded bricks are usually dried in ovens which are heated. The

bricks remain in these ovens for two or three days' time depending upon the amount of moisture which must be evaporated.

Burning of the Molded Shapes. The kilns used to burn the bricks are actually large ovens. The bricks are stacked in the kilns in such a manner that ample space is left so that flames may circulate freely. Between 75 and 100 hours is required generally for the complete process including the cooling of the bricks. Kilns must be heated gradually to drive off any remaining moisture in the bricks. This stage in the burning process is known as *water smoking*. The temperature, after water smoking, is gradually raised until it reaches the vitrification point—the point at which the materials composing the bricks begin to fuse.

After firing, the heated bricks are gradually cooled to avoid checking of their surfaces.

KINDS OF BRICK

There are many kinds of brick. Some of them are different in formation and composition while others vary according to the use to which they may be put. Some are made for economy, some for strength, some for appearance, and some for special uses, such as for fireplaces. The kinds of brick most commonly encountered are explained in the paragraphs that follow. It should be repeated that brick specifications can be obtained that will serve as a guide for selecting and purchasing brick for any purpose.

Common Brick. The term common brick is applied to bricks made of ordinary clays or shales and burned in the usual manner in kilns. Such brick do not have special scorings or markings and are not produced in any special color or surface texture.

There are grades of common brick which vary in different parts of the country. In some localities, all the brick coming from the kilns are sold without any grading even though there may be a difference in their hardness and strength. In other localities, the bricks are graded and sold as front and back bricks. The front bricks are those burned to the greatest degree of hardness. Common brick is also known as hard and *kiln-run* brick. When bricks are overburned in the kiln, they are called clinkers. Such bricks are unusually hard and durable. Because of the way in which the heat is applied in some types of kilns, the bricks are

classified according to their position in the kiln. Typical classifications are *arch, clinker, red, well-burned, soft, salmon, rough-hard, straight-hard,* and *stretcher.*

Arch and clinker bricks are those which have been overburned and are thus extremely hard and durable. These bricks may be slightly irregular in shape and size.

Red, well-burned, and straight-hard are well-burned, hard, and durable. Stretcher brick are selected from these classifications as the most uniform in hardness, size, and durability.

Rough-hard brick correspond to the clinker classification.

Soft and salmon brick are those which were farthest from the fire in the kiln and are therefore underburned, soft, and not as durable as the other classifications described. It should be pointed out that in certain localities the existing clay is of such composition that hard and durable bricks are salmon in color.

There may be other classifications or names for common brick. However, the important thing is to determine the hardness and durability of the bricks before they are laid up as structural work.

Face Brick. This kind of brick is made of especially selected materials in order that colors and textures can be controlled, and so that hardness, size uniformity, and strength are all of high classification. These bricks may have various markings or surface finishes, all of which are aimed at producing walls of pleasing appearance.

Pressed Brick. Both common and face brick may be classified as pressed brick depending on the materials used, their coloring, and burning. The dry-press process is used to make this class of brick which has regular smooth faces, sharp edges, and perfectly square corners. Ordinarily, all pressed brick are used as face brick.

Firebrick. This kind of brick is made from a special type of fire clay which will stand the high temperatures found in fireplaces, furnaces, etc., without cracking or decomposing. Firebrick is generally larger than regular structural brick and often hand-molded.

Glazed Brick. This type of brick has one surface of each brick glazed in white or any other color desired.

Imitation Brick. This kind of brick is similar to common brick in size and use but is made of Portland cement and sand. They are not burned but have the same qualities as good cement mortar.

PHYSICAL CHARACTERISTICS OF BRICK

Size of Brick. The United States Bureau of Standards recommends that brick sizes should be as shown in Table I.

TABLE I. STANDARD BRICK SIZES*

KIND	DEPTH INCHES	WIDTH INCHES	LENGTH INCHES
Common	2¼	3¾	8
Rough-faced	2¼	3¾	8
Smooth-faced	2¼	3⅞	8

*Permissible variables are: plus or minus 1/16″ in depth, ⅛″ in width, and ¼″ in length.

Rough-faced brick are those which have been formed so that their faces are irregular. Smooth-faced brick are those whose surfaces are smooth like pressed brick. Most face brick are of the latter type.

Weight of Brick. The weight of brick varies because of the materials used in their manufacture, the amount of burning, and their sizes. Since every manufacturer produces brick of different weight, such information should be obtained directly from him. An approximate weight, especially of common brick, is about 4½ pounds each.

Quality of Brick. Brick should be uniform in shape and size; their edges should be fairly square, straight, and well defined; they should be free of cracks, pebbles, twists, and broken corners; and should be well burned but not vitrified or brittle. A good test of bricks is to strike two of them together. They should emit a metallic ring. Surfaces should not be too smooth because some roughness is required to assure good bonding with the mortar. A good brick should not absorb more than 10 to 15 per cent of its weight in water after having been soaked in water for 24 hours.

Colors and Surface Finishes of Brick. In general, the brick produced in the United States from natural clays and shales without special mixing are red in color. There are a few localities where the materials available produce bricks which tend to be yellow. The slight difference in the clays and shales and the manufacturing processes account for these various shades of red and yellow. Some difference in color also is possible between burnings which make it advisable to purchase enough bricks for a job all at one time to assure the same coloring.

Such minerals as iron, lime, and magnesia are responsible for the

coloring in bricks. These minerals occur naturally in the clays and shales. For example, iron in clay will produce yellow, orange, red, and blue. Magnesia produces a brown color. When the manufacturer carefully controls the amounts of these minerals he can produce bricks of almost any desired color provided he also controls the amount of heat in the kiln. Kiln heat also plays an important part in the production of colors.

Many surface textures in face bricks are possible by various steps in the manufacturing. For example, rough textures can be obtained by mixing coarse materials with the other brick materials or wires can be used to cut the bricks as they are extruded from a die. Wire cutting produces a type of finish or texture which is pleasing to the eye. There are many possible textures produced. Brick manufacturers will supply literature relative to their products free of charge. Such literature can be used in selecting texture.

GENERAL BRICK MASONRY DEFINITIONS

There are some general terms which must be known and understood in connection with brick masonry before the following parts of this chapter are studied. Such terms are given in the following:

Air space—a space or cavity in walls or between various structural members.

American bond—a method of bonding brick in a wall whereby a header course occurs every 5, 6, or 7 courses in the wall.

Arch—brickwork built to support not only its own weight, but also the weight of the wall above it and over an opening in the wall.

Backing—the rough brickwork back of the facing brickwork in a wall.

Backing-up—the process of laying the backing.

Brick veneer—a 4″ tier of brickwork used as facing for a wall constructed of other materials.

Buttering—the process of throwing mortar on a brick prior to its laying.

Chase—an opening or channel in a brick wall to allow space for piping.

Column—a round or square pillar or post used to support portions of a building above it.

Common brick—ordinary or cheap brick.

Coping—a covering used to cap wall tops.

Course—one horizontal row of brick in a wall.

Efflorescence—a white, salt-like powder or coating which forms on the faces of brick walls.

Fat mortar—mortar which has little sand in it and which is sticky.

Fire clay—a kind of clay which can stand high heat without softening, burning, or decomposing.

Frame-high—the top of window and door frames or the level at which a lintel is placed.

Grout—a very thin mortar which can be poured.

Header—a brick is a header when it is laid in a wall so that its end shows in the wall face.

Header-high—when a portion of a wall has been laid up to the point where headers are necessary, the wall is said to be header-high.

Jamb—the sides of a window or door opening or framework.

Jointing—the process of finishing the mortar joints.

Lap—the distance one brick extends beyond or over another.

Lead—part of a wall built as a guide for the laying of the balance of the wall.

Lintel—a support over window and door openings.

Mortarboard—a square board or platform on which mortar is placed during the laying of brickwork.

Neat cement—mortar made only of cement and water.

Pargeting—the process of plastering the inside of a chimney flue or wall.

Pilaster—a column constructed as part of a wall.

Pointing trowel—a small trowel or tool used to fill joints in brickwork.

Span—the distance across a door or window opening.

Stretcher—a brick laid in a wall so that its long edge is parallel to the face of the wall.

Tier—a vertical pile or layer of bricks 4″ wide.

Other brick masonry terms are explained in following pages as the need for an understanding of them occurs.

WHERE BRICKS ARE USED

Bricks can be and are used for many structural purposes including all kinds of walls and partitions, footings and foundations, columns, pilasters, chimneys and fireplaces, furnaces, sidewalks and steps, floors, garden walls, arches over wall openings, parapets, and pavements. The possible uses of brick are practically unlimited.

Common Brick. Generally, this kind of brick is used for the backing courses in solid or cavity brick walls. The harder and more durable kinds are preferable for this purpose. If a wall is to have a stucco exterior finish, a good grade of common brick can be used for all tiers. In some cases, selected and well-burned common brick in various shades of red or tan are used as face brick with good results.

The softer common brick, such as the salmon classification, should not be used for backing or as face brick in any wall or other structure which must support heavy loads. These softer brick should be used only in partitions or other walls which have no appreciable weight to support and where they are not exposed to the weather.

Good grades of common brick can be used for garden walls, sidewalks, columns, piers, steps, and other such typical construction, with good results.

Face Brick. This kind of brick is used generally for all veneering and exterior tiers in outside walls and chimneys of residences and other buildings. Sometimes face brick are used only in those exterior tiers which are visible from the street. In such cases, those exterior tiers not visible from the street should be laid up using well-burned common brick. This kind of brick also can be used for garden walls, walks, and steps, where exceptionally good appearance is desired, regardless of expense.

Pressed Brick. As previously explained, both common and face brick can be of the *pressed* brick classification. However, while many types of face brick are produced by this process, only the better grades of common brick are of the pressed-brick variety. Pressed brick make excellent face brick for exterior tiers of solid or cavity walls and for veneering. This kind of brick is especially useful when exact dimensions are desired in walls or other structural members. They can be classified the same as face brick unless specifically described as common brick.

Firebrick. These brick should be used only to line the interior surfaces of fireplaces, boiler furnaces, etc., where extreme heat is encountered.

Glazed Brick. These brick, because their exposed surfaces are glazed, make excellent exterior tiers for walls or partitions in dairies, hospitals, and other buildings where cleanliness and ease of cleaning is an important factor.

Imitation Brick. This kind of brick can be used any place where the usual common, pressed, or face brick can be used.

There are many other uses for the various kinds and grades of brick, all or any of which can be discussed with building material dealers or manufacturers.

BONDING AND TYPES OF BONDS

In order that walls, partitions, chimneys, and other structural members will be strong, solid, and durable, it is necessary that the brick be placed in such a manner that they are all tied together to

form a cohesive block or mass. The mortar in the horizontal and vertical joints tends to tie all brick together but unless the individual brick is placed and bonded properly, a wall, for example, will not have much strength or durability, especially when it supports heavy loads. The process of tying a wall or other unit masonry structure together is called *bonding*. Good bonding is accomplished only by lapping one brick across or over at least two other bricks in the course below it. This method is also known as breaking joints.

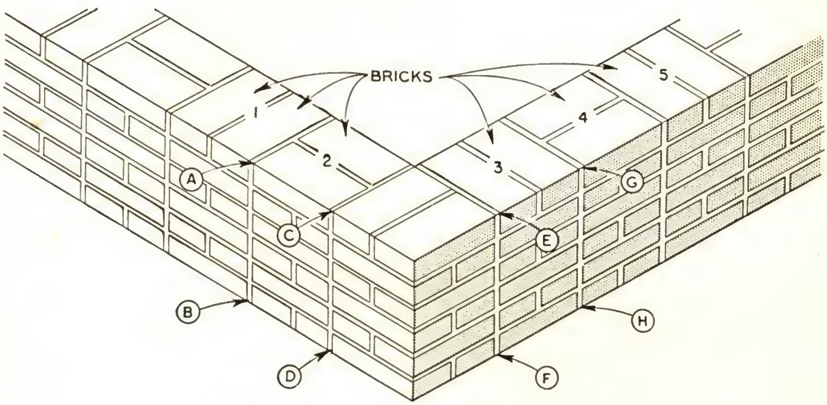


Fig. 1. Improperly Bonded Brick Wall

Fig. 1 shows an 8″ brick wall which is improperly bonded. In this wall, the bricks are placed so that the wall is merely a series of piers or columns that abut each other. These piers or columns are cross-hatched at the top and numbered *1, 2, 3, 4,* and *5*. There is no bond between them except the mortar in the joints *AB, CD, EF, GH,* etc. While the mortar does hold the piers or columns together, it is not sufficient to make the wall a solid, cohesive mass as is necessary. A wall built in this manner would, when loaded, crack open along the joints previously mentioned, thus losing much of its strength and durability. It would not be structurally safe or dependable for any type of construction.

Fig. 2 shows an 8″ brick wall which is properly bonded. Note that each of the stretchers rests on two bricks in the course below and that the vertical joints are not continuous but are broken from course to course. When headers are laid up in such a wall, they, too, as

illustrated in Fig. 2, rest on two bricks in the course below. It can be seen that proper bonding ties the wall together in both the direction of the length of the wall and in the direction of the height of the wall.

The foregoing explanation illustrates the principle and purpose of bonding. Several typical examples of bonding are explained and illustrated in the following pages.

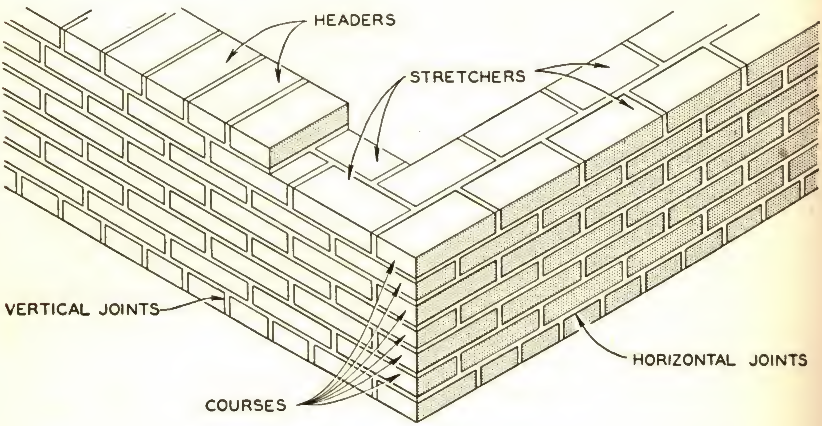


Fig. 2. Properly Bonded Brick Wall

Stretcher Bond. The bond shown in (A) of Fig. 3 is known as a *stretcher* bond because the bricks in all courses are laid as stretchers. This bond is used extensively for brick veneering and for partitions which are only the thickness of a single tier of brick.

Header Bond. The bond shown in (B) of Fig. 3 is known as *header* because the bricks in all courses are laid as headers. This bond can be used for walls or partitions 8″ thick.

Common Bond. The bond shown in (C) of Fig. 3 is known as *common* bond and is perhaps the most generally used bond. It can be seen that every sixth course is a header course and the intervening courses are stretcher courses. Sometimes masons vary this bond to an extent by laying a header course every fourth or fifth course. This variation has a tendency to straighten the brickwork but for ordinary cases is not necessary. This bond is used extensively for building walls, especially when common brick are used, and for backing up

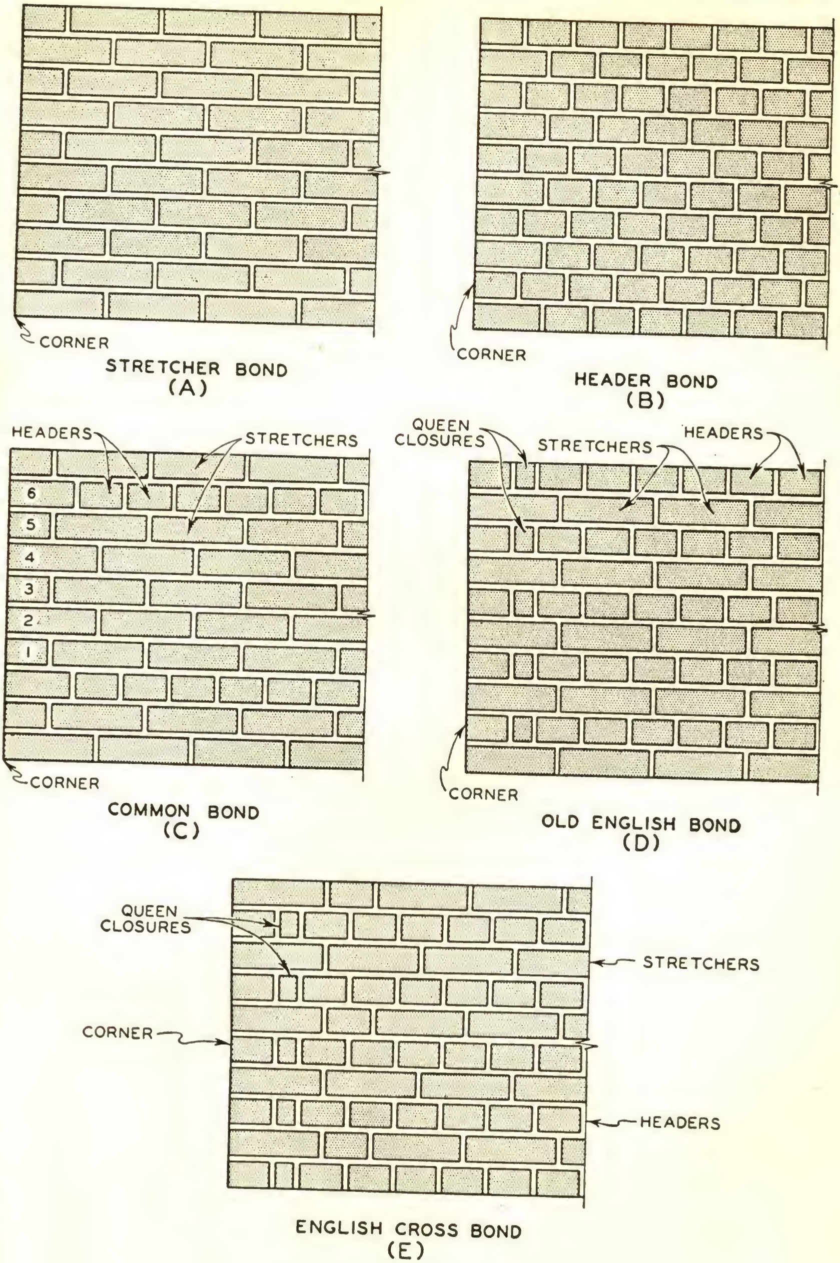


Fig. 3. Some Typical Bonds

stone, terra cotta, and face brick. It is also used to back up or face hollow tile and concrete block walls.

Old English Bond. The bond shown in (D) of Fig. 3 is known as *Old English* bond and is one of the popular bonds used, especially for residence walls. This bond is produced by alternating a course of stretchers with a course of headers. A *closure* is laid next to the corner bricks in every course of headers.

Closures are parts of bricks used as a means of obtaining desired bonds at the corners of walls, as shown in (D) of Fig. 3. They are often called *bats* instead of closures. If a brick is cut in half paralleling the long dimension, each half is called a queen closure. When a fourth of a brick is cut off, the remaining part is called a three-quarter bat or closure. When a brick is cut in half across the 3¾″ or 3⅞″ face, both halves are known as half-bats or closures. A one-quarter brick is known as a quarter-bat or closure. The closure shown in the Old English bond is a queen closure. Or, two quarter-closures may be used.

English Cross Bond. The bond shown in (E) of Fig. 3 is known as *English Cross* bond. This bond differs only slightly from Old English bond. It is used for walls where strength and beauty are required.

Dutch Bond. The bond shown in (A) of Fig. 4 is known as *Dutch* bond. This bond is laid up using three-quarter and half closures together with regular headers and stretchers.

Flemish Bond (Double). The bond shown in (B) of Fig. 4 is known as *Flemish Double bond.* It is laid up using queen or quarter-closures, headers, and stretchers.

The English, Dutch, and Flemish double bonds are rarely used in this country because of the care needed in their laying. However, they make beautiful strong walls.

Bonding Face Brick. When face brick are laid as an exterior tier and backed by common brick, they must be bonded to the backing. This can be accomplished in two ways. If the facing bond has courses of headers, these headers can be face brick and bonded into the common bricks like any other header course. Or, if the face brick tier is laid in stretcher bond, such as in (A) of Fig. 3, metal ties must be used as anchors.

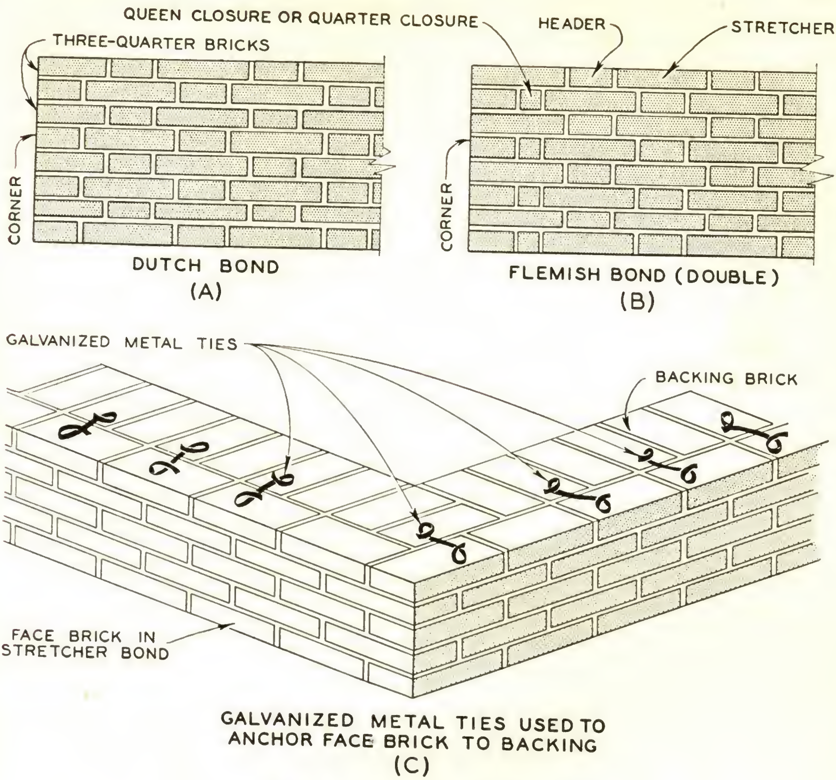


Fig. 4. Other Typical Bonds

In (C) of Fig. 4 is shown a 12″ brick wall having face brick laid in stretcher bond and anchored to the backing by means of galvanized metal ties. These ties are spaced two or three bricks apart horizontally as part of the mortar joint. For best results they should be laid in at least every other course.

Eight-inch Rolok-Bak Wall. Fig. 5 shows a type of cavity wall often employed where economy is essential and where the wall loads are not great. The interior tier is composed of bricks laid on edge in stretcher bond. The exterior course is composed of bricks laid flat in stretcher bond. Every seventh course is composed of headers which span the distance across the two tiers. The mortar joints in the exterior tier must be made thicker than those in the interior tier in order that the tops of both tiers will be at the same level at every

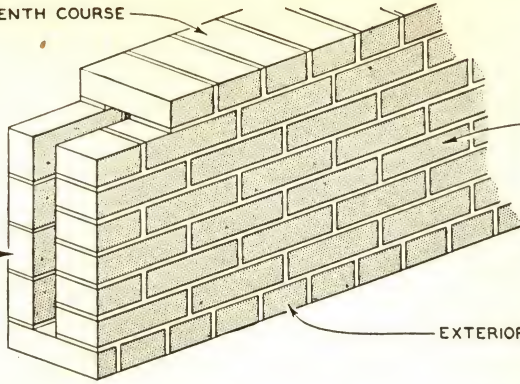


Fig. 5. Eight-Inch Rolok-Bak Wall

seventh course. The reason for this can be understood when it is noted from Fig. 5 that the interior tier, composed of four courses of bricks laid on edge, equals 4 × 3¾″ or 15″ (not counting joints), whereas the exterior tier, composed of six courses of bricks laid flat, equals 6 × 2¼″ or 13½″ (not counting joints).

Soldier Courses. A soldier course, as shown in (A) of Fig. 6, is composed of bricks embedded in walls so as to stand on end with only edges showing. Because of this upright position, such a course cannot be bonded into the wall of which it is a part. This has a tendency to weaken the wall, although not seriously.

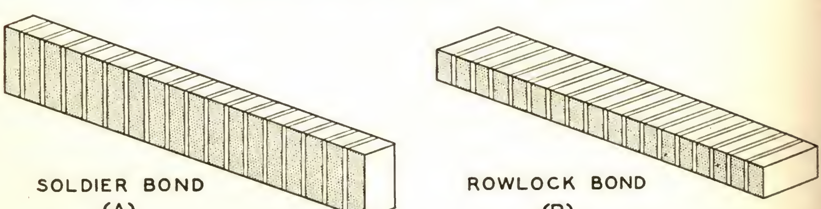


Fig. 6. Typical Bonds

Soldier courses are used mainly as a water table around a building at the level of the first floor. They are also used in laying flat arches on steel lintels over windows, doors, and other wall openings.

Rowlock Courses. A rowlock course, as shown in (B) of Fig. 6, is composed of bricks embedded in walls so as to lie on edge with only

ends showing. Three rowlocks should be the same length as a stretcher in the face of a wall.

Rowlocks are used as sills, borders, and parts of cornices and may be used also as coping and steps and in arches.

Good bonding without a doubt is one of the most important features of any brick masonry and therefore should be given the most careful attention by the masons doing the bricklaying. Careless work invariably results in walls or other structural parts which are unsightly, unsafe, and undependable from the standpoint of durability. Inexperienced masons should practice laying various bonds using scrap brick until they have developed the skill necessary to produce first-class work. Additional explanation relative to bricklaying is given in succeeding pages.

BRICKLAYING TOOLS

Bricklayers, unlike most other mechanics, need but few tools. Ordinarily, the following named and described tools are sufficient.

Plumb Rule. The plumb rule or spirit level is the tool necessary to guide the bricklayer in building walls or other structural parts, plumb and level. The modern plumb rule varies in length from 36″ to 48″ and is generally made of wood although metal is sometimes used in its construction. The better plumb rules have two level glasses at the center (midway between the two ends) and two plumb glasses near each end. These glasses are usually adjustable and well protected against breakage.

Such an instrument is a combination plumb rule and level. As a level, it is used in a horizontal position, in which case the glass at the center indicates the level. As a plumb rule, the tool is held with one edge against the brickwork and the upper of the two end glasses observed. No brick masonry can be laid without such a tool.

Trowels. The most important tools a bricklayer uses are his trowels. Typical trowels and their uses are illustrated in the how-to-lay-bricks section of this chapter. The large trowel, which is used most generally in ordinary bricklaying, is usually from 9″ to 11″ in length and from 4″ to 7″ or 8″ in its greatest width. The small trowel is generally from 4″ to 7″ in length and from 2″ to 4″ wide. For pointing work, some masons use an even smaller trowel which is from 3″ to 6″ in length and from 2″ to 3″ in width.

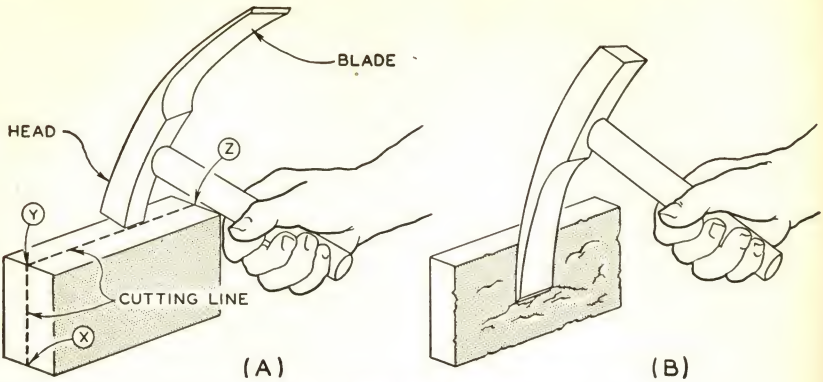


Fig. 7. The Brick Hammer

Brick Hammer. In order that a mason can make closures and bats as required in bonds and in other places such as around steel lintels, a peculiar kind of hammer is necessary as illustrated in (A) and (B) of Fig. 7. The hammer in this illustration is being used to make a queen closure. The first step, as shown at (A), is to make the cutting line all the way around the brick. This line is made by light blows of the hammer. When the line is complete, one sharp blow is given about as shown at (A), causing the brick to split. Rough places are trimmed using the blade of the hammer as shown at (B). Cutting bricks cleanly and correctly requires a great deal of practice which can be had using scrap bricks.

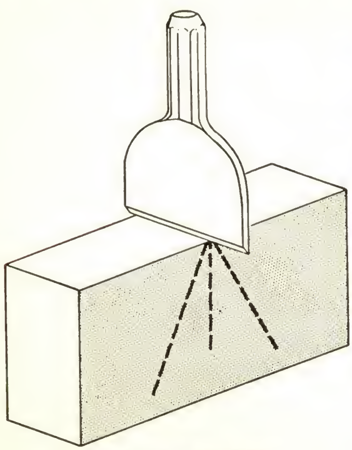


Fig. 8. The Brick Set

Brick Set. This tool, shown in Fig. 8, is used to cut bricks when more exact surfaces are required. The hammer is used to force this tool into the brick.

Jointer. This tool is used to make other than struck (explained in the following pages) joints. There are various kinds of such tools, all of which accomplish the same end. Their edges are rounded, pointed, etc., to make the required shape in the mortar as they are drawn along the joint.

Line. The line is also an important tool. It is usually a stout piece of cord.

Square. This tool, which is the same as the carpenter's tool, is required for corners and in laying out walls.

In addition to the tools just described, miscellaneous items such as chalk, pencils, and knives generally can be found in the brick mason's tool kit.

Mortarboard. Most bricklayers prefer a mortarboard which is about three feet square. Sufficient quantities of mortar can be kept on a board of that size and there is ample space for the mortar to be worked by the bricklayer to keep it in the proper condition. Generally, mortar should be kept well rounded up rather than spread all over the board as this tends to prevent the formation of lumps in it.

MORTAR

Important Functions of Mortar. Ordinarily, mortar is thought of only as a means of bonding or sticking together, the bricks used in building walls and other brick masonry structural items. This is one of the most important functions of mortar. In addition to this, it forms a cushion which takes up all irregularities in the bricks and tends to distribute equally the weight or pressure in the various parts of, for example, a wall. This adds to the strength of brick masonry. Thus, mortar not only bonds all bricks together to form a solid mass but it also causes the mass to act with equal pressure throughout as in concrete.

There are other important functions of mortar which should not be overlooked. For example, it makes brick masonry largely waterproof and airproof. When all joints are properly made, a brick wall, in addition to supporting the building, also keeps out moisture and the dust and dirt carried in the air.

Recommended Mortars. The chapter on mortar in a preceding part of this book gives a complete discussion and description of mortar. This chapter should be studied carefully as it contains information which every mason must understand thoroughly before he can prepare or supervise the preparation of mortar for any brick masonry job.

All mortar should be well mixed and neither too stiff nor too

plastic. The degree of plasticity should be such as to make for easy working of the mortar with the trowel.

Properties of Mortar. The properties of mortar depend to a large extent upon the type of sand used in it. If the sand is *sharp, clean,* and *well screened,* the mortar should be excellent. When very fine sand is used, there is less give to the mortar, the water works out of it, and it becomes stiff and difficult to work with a trowel. Also, when sand is too fine, the mortar is apt to set before the bricks can be placed easily.

In some localities, sand occurs in banks and in some instances, to a large extent forms the soil. Under no condition should such sand be used for making mortar unless it is tested and washed as explained in the chapter on concrete in the first portion of this book. Even then, such sand may be too fine for ordinary mortar. Too much sand in any mortar causes the bricklayer to drop considerable mortar off the trowel. This is because the excess of sand robs the mortar of its ability to hang together.

Once mortar has set it should not be disturbed. If it is disturbed, it will not properly unite and becomes quite useless.

There are many prepared mortars for sale under different trade or manufacturers' names. These can be used successfully providing they are mixed according to the manufacturer's directions and providing they meet the standard specifications outlined in the chapter on mortar in this book.

Often smooth-textured face bricks are laid with small or thin bed joints. In order to make mortar which can be spread to make joints as thin as ⅛", it is necessary that it be of fine texture. This can be accomplished by using sand which is fine in character. (This is in direct contradiction to foregoing explanations relative to sand and is the only permissible exception to the rule.) Mortar for thin joints should be "fat" and is known as "buttering" mortar.

Frozen Mortar. If mortar freezes, it should not be used. The freezing destroys its bonding ability and renders it entirely worthless.

Mortar Color.[1] Color is sometimes added to mortar as a means of making it contrast with the color of the bricks, thus producing a wall of pleasing appearance.

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[1] See also Chapter II on mortar.

The coloring matter can be purchased either as a dry powder or in the form of paste. Most masons prefer the paste as it seems to mix more readily with mortar. Coloring material should not be added to the mortar until the lime has been slaked at least a day. Then the mixing must be carefully and thoroughly done according to the manufacturer's directions. The color of mortar when wet will be darker than when it has dried. Therefore, the inexperienced mason should mix a sample before the entire mix.

WETTING BRICKS PRIOR TO LAYING

When bricks are laid during warm weather, especially during hot and dry weather, they should be thoroughly wetted but not soaked to the saturation point just prior to the time they are laid. The wetting can be done with a hose or some form of water sprinkler which will just wet the bricks enough so that they look wet all over their surfaces.

There are four reasons for wetting bricks just prior to their laying:

a) The bricks will tend to more evenly spread the mortar under them (this is known as *bedding*) and thus facilitate a better mortar joint.

b) The bricks will adhere better to the mortar.

c) A dry brick will quickly absorb water from the mortar. This is particularly dangerous when using cement mortar which will not properly dry (set) unless it dries slowly and in a moist condition. The danger is not so pronounced when lime mortar is used as this type of mortar sets by oxidation.

d) Wetting bricks washes the kiln dust from them. A clean brick will produce a better joint or bond with the mortar.

When bricks are laid in cold weather, they should not be wetted.

LAYING BRICKS IN COLD WEATHER

It is best not to lay bricks in cold weather but when it cannot be avoided, the following directions should be followed.

In contrast to the wetting procedures used when laying bricks in hot and dry summer weather, bricks laid during cold weather must be absolutely dry. If possible, they should be warmed before being used. Mortar should be made using hot water and hot sand. Care should be taken not to use hot lime in making mortar because when hot it is not completely slaked and in such condition would cause undesirable results. If salt is added to the mortar water as a means of preventing freezing, it is possible that some efflorescence will occur.

PROPER JOINTS IN BRICKWORK[1]

As bricklayers are laying up walls, for example, they should keep in mind that unless the mortar joints are made *properly,* the mortar will fail to some extent, in one or all of its required functions. Mortar joints must be made *carefully* and properly. The importance of this cannot be overemphasized. Excellent bricks and excellent mortar cannot produce good walls or any other structural items unless the mortar is properly applied. Much of the brick masonry done in the past has been poor only because of carelessness in the use and application of the mortar in the horizontal and the vertical joints in brickwork.

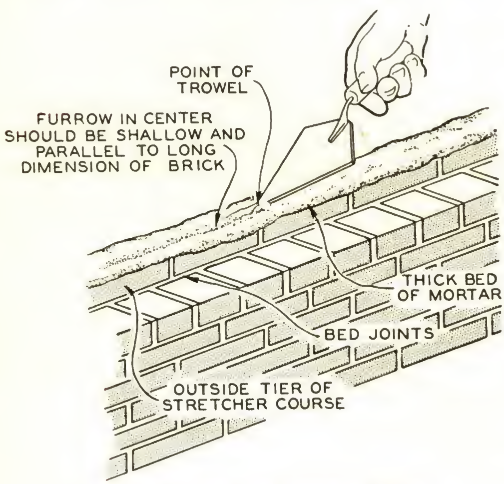


Fig. 9. Proper Bed Joints in Walls

Bed Joints in Stretcher Courses. A bed joint, as illustrated in Fig. 9, is a horizontal joint upon which bricks rest. Bed joints are important from the standpoints of bonding bricks together, creating equal pressure throughout a wall, and making the wall moistureproof and airproof.

Mortar for bed joints should be spread thick as indicated by the thick bed of mortar under the trowel in Fig. 9. The mortar can be one inch or more in thickness. It is customary to run the point of the trowel along the mortar, as shown in the illustration, to make a furrow. This furrow should be along the middle of the mortar bed and should be shallow, not deep. It is not advisable to spread bed mortar more than a distance of four or five brick lengths in advance of laying. This is especially important during hot and dry weather. By spreading the bed not more than a few brick lengths in advance of laying, the mortar remains soft and plastic and allows bricks to be laid (bedded) easily and properly. Another advantage is that the

[1] See also Chapter II.

mortar does not have a chance to dry out much before the bricks are bedded and thus sticks to the bricks as they are placed.

Head Joints in Stretcher Courses. A head joint, as illustrated in Fig. 11, is a vertical joint which joins bricks together at their ends. Head joints are also important, especially from the standpoint of preventing cracks in the wall and making the wall moistureproof and airproof.

Head joints, like bed joints, must be *completely filled with mortar.* There are different ways in which this can be accomplished. Plenty

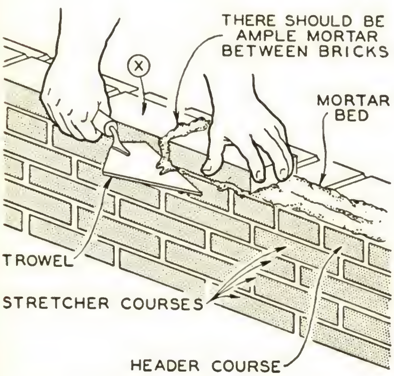


Fig. 10. Proper Head Joints in Walls

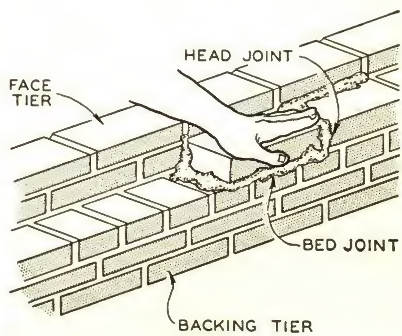


Fig. 11. Proper Bed and Head Joints for Backing

of mortar, as thick as will stick, should be thrown on the end of each brick to be placed. This should be done in such a way that the mortar will be scraped off the trowel by the bottom edge of the end of each brick. The bricks can then be placed on the mortar bed and pushed into place, as shown in Fig. 10, so that the excess mortar squeezes out at the head joint and at the side of the wall. Or, a dab of mortar may first be spotted on the corner of the brick, such as brick *X* in Fig. 10, already in place. This is followed by placing additional mortar on the end of the brick to be laid. The brick to be laid is then pushed into position as previously explained.

Both of the methods described in the previous paragraph succeed in making a full head joint. These methods are the *only* methods a good bricklayer should use.

Bed and Head Joints for Backing in Stretcher Courses. Fig. 11

shows part of a wall in which the face tier has been laid up ahead of the backing tier. The bed and head joints here are also important.

The best method for making good bed and head joints as backing is laid is as follows: A large trowelful of mortar should be thrown at the place where backing bricks are to be laid. Plenty of mortar should be used—all that can be carried by the large-sized trowel. Then the bricks should be shoved into this deep mortar so that it oozes out from the bed and head joints as shown in Fig. 11. This method makes absolutely certain that joints are full of mortar at every point.

Cross Joints in Header Courses. Cross joints also should be carefully made to assure their being *absolutely filled with mortar.*

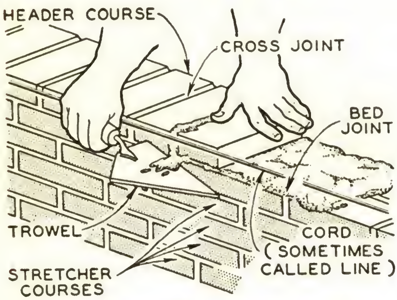


Fig. 12. Proper Cross Joints in Walls

First, plenty of mortar should be spread, several brick widths in advance, to form the bed joint. This mortar should be up to an inch thick and evenly spread. Before each header brick is laid, the edge shown in Fig. 12, the header should be entirely covered with all the mortar that will stick to it. Then, as shown in Fig. 12, the header should be shoved into place so that mortar oozes out above the cross joint as well as at the bed joint. The excess mortar is scraped off with the trowel.

Closure Joints in Stretcher Courses. The last brick to be placed in a stretcher course must be laid so that both head joints are completely filled with mortar.

With the bed joint mortar already in place, the first step in laying a closure is to apply plenty of mortar to the ends of bricks X and Y in Fig. 13, which are already in place. Also, ample mortar should be thrown on the two ends of the brick to be placed. The mortar should entirely cover the two ends. Finally, the closure should be laid as indicated in the illustration, without disturbing the brick already in place.

Closure Joints in Header Courses. The laying of a closure brick in a header course is illustrated in Fig. 14. Before laying the closure brick, plenty of mortar should be placed on the sides of both bricks

already in place. Also, mortar should be carefully and amply spread on both edges of the closure brick so that the edges are completely covered to a thickness up to an inch. Then the closure should be laid without disturbing the bricks already in place.

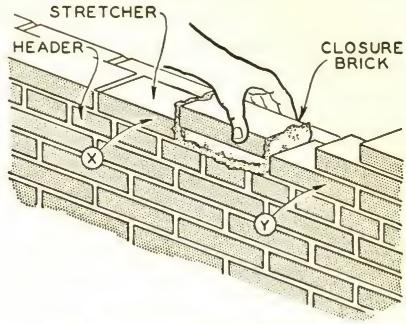


Fig. 13. Proper Closure Joints in Walls

No matter what kind of brickwork is being laid—thick joints or thin—the joints should be completely filled. Any deviation from this rule is poor bricklaying.

Finishes of Joints. The finishes of joints at the surface of the brickwork is for the purpose of making the brickwork more waterproof and pleasing to the eye. Several types of joint finishes are employed. A few typical joint finishes are shown in Fig. 15. There are other types, but none are in common enough use to include here.

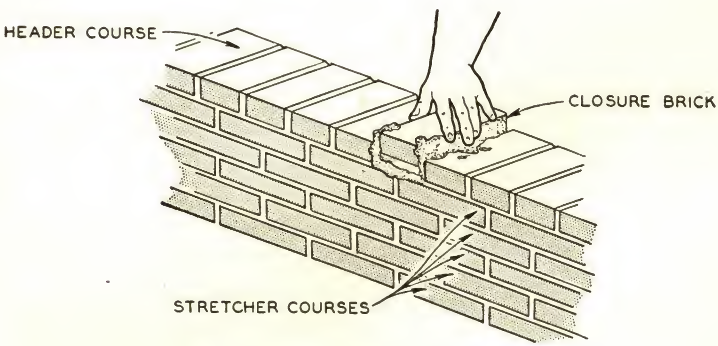


Fig. 14. Proper Closure Joints in Walls

The practice of finishing a joint simply by drawing one edge of the trowel along it and scraping the excess mortar off is not recommended. For example, suppose a bricklayer finished the joint, in (A) of Fig. 15, by such a process. If he drew the trowel upward there probably would be a crack between the mortar and the brick at Y. If he pushed the trowel downward, the crack might occur at X. Whichever way the edge of a trowel is drawn across a joint, the joint is left

in an improper condition. The remedy is to use the trowel or a pointing tool as explained in the following descriptions.

FLUSH JOINT. This joint is shown in (A) of Fig. 15. It can be made by keeping the trowel almost parallel to the face of the wall while drawing the point of the trowel along the joint.

WEATHER JOINT. This joint is shown in (B) of Fig. 15. It is a joint designed to shed water more easily from the surface of the wall. This joint is made by striking it downward with the top edge of the trowel. In other words, the top of the mortar joint is mashed in with the top edge of the trowel.

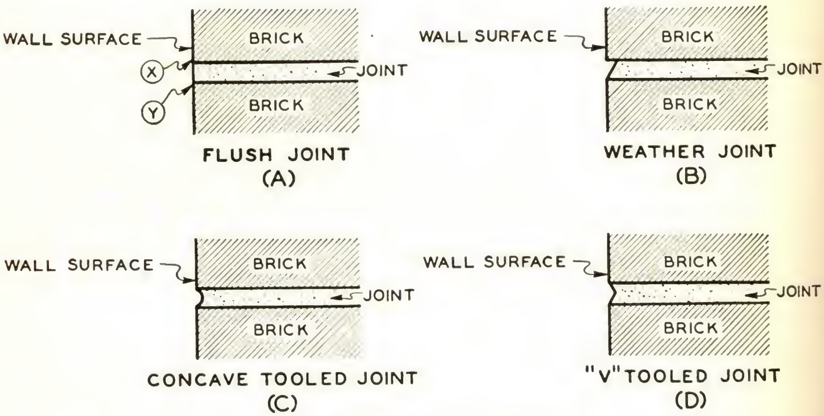


Fig. 15. Proper Finishes of Joints

V AND CONCAVE TOOLED JOINTS. These joints are shown in (C) and (D) of Fig. 15. Special pointing tools are required to make them. Excess mortar is removed with the trowel after which the joint tools are employed. The **V** and concave tooled joints are perhaps the best joints under ordinary conditions. The finishing of joints should be done before the mortar hardens to any appreciable extent.

Parging. Parging, or the plastering of brick tiers, is a good means of making walls more moistureproof and airproof. Fig. 16 shows a wall being back-plastered. The plaster is applied to the back of the facing tier. This is done between header courses and should be about 3/8″ thick. Regular mortar can be used for the purpose. This back-plastering can be omitted if desired and the backing tier laid as indicated in Fig. 11.

Thicknesses of Mortar Joints. The matter of joint thicknesses cannot be stated very well as a hard and fast rule because of the many possible variables which are encountered.

Bricks made by either the stiff- or soft-mud process are likely to be somewhat irregular in shape and thus must be laid up using mortar joints approximately ½″ thick. This varies according to the condition of the brick. The thinner mortar joints, such as ¼″, are the strongest and should be used whenever possible. Bricks manufactured by the pressed process are likely to be regular enough in shape to allow the use of ¼″ mortar joints.

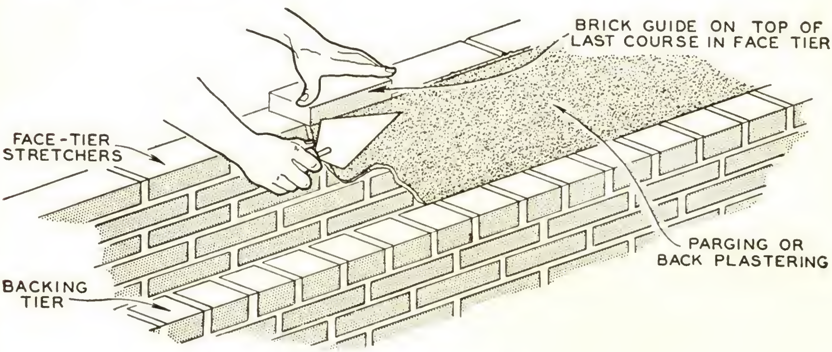


Fig. 16. Parging

When walls have face tiers made of common or rough-textured bricks, the mortar joints in these face tiers are sometimes made up to ¾″ in thickness. In such cases, the joints in the backing tiers are adjusted either by additional courses or thicker mortar joints than usual so as to bring the two tiers at the same level at the header courses. Another condition, somewhat the same, was explained relative to Fig. 5.

When colored mortar is used in face tier joints, the thickness of the joints is frequently decided by the effect of the color in the wall surface. When light-colored bricks are used as facing, thin, colored mortar joints give the principal effect. Usually, however, the wider the colored mortar joint, the more colorful the wall will be.

For ordinary brick masonry, the mortar joints should be made as near to ¼″ as possible.

Joints for Firebrick. Special fire clay mortar is required for firebrick. Such mortar can be purchased ready to mix for use. Very little

mortar should be used in firebrick joints. If such bricks do not fit snugly together, one or more of them should be cut until they do fit.

TYPICAL BRICK MASONRY DETAILS

Some typical brick masonry details which will help the reader to visualize construction procedures are illustrated and briefly discussed in the following paragraphs.

Bond Details. A few typical bond details showing how bricks are laid up in courses, are set forth in the following descriptions.

COMMON BOND. Details of this bond are shown in the how-to-lay-brick section of this chapter.

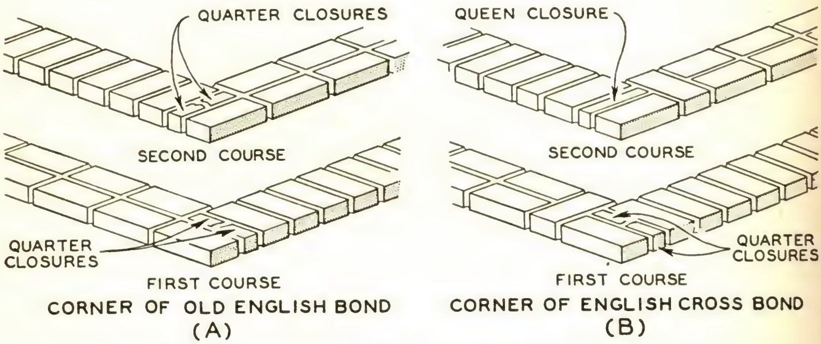


Fig. 17. Bond Details for Old English and English Cross Bond

OLD ENGLISH BOND. In (A) of Fig. 17 is shown the first and second courses of this bond. Note that quarter closures are used in alternate courses on either side of the corner. This is the same bond as illustrated in (D) of Fig. 3.

ENGLISH CROSS BOND. In (B) of Fig. 17 is shown the first and second courses of this bond. Note that this bond differs only slightly from Old English Bond. Refer to the illustration in (E) of Fig. 3.

DUTCH BOND. In (A) of Fig. 18 is shown a built-up corner of this bond consisting of two courses. Note that half and three-quarter closures are used at the corners. This is the same bond as illustrated in (A) of Fig. 4.

FLEMISH BOND (DOUBLE). In (B) of Fig. 18 is shown the first and second courses of this bond. Note that quarter closures are used near the corners. This is the same bond as illustrated in (B) of Fig. 4.

Stretcher Bond. In (C) of Fig. 18 is shown two courses for a corner of this bond. This is the same bond as illustrated in (A) of Fig. 3.

Brick Veneer Details. Fig. 19 illustrates typical brick veneer on a wood-framed and sheathed wall. Note that the stretcher-bonded

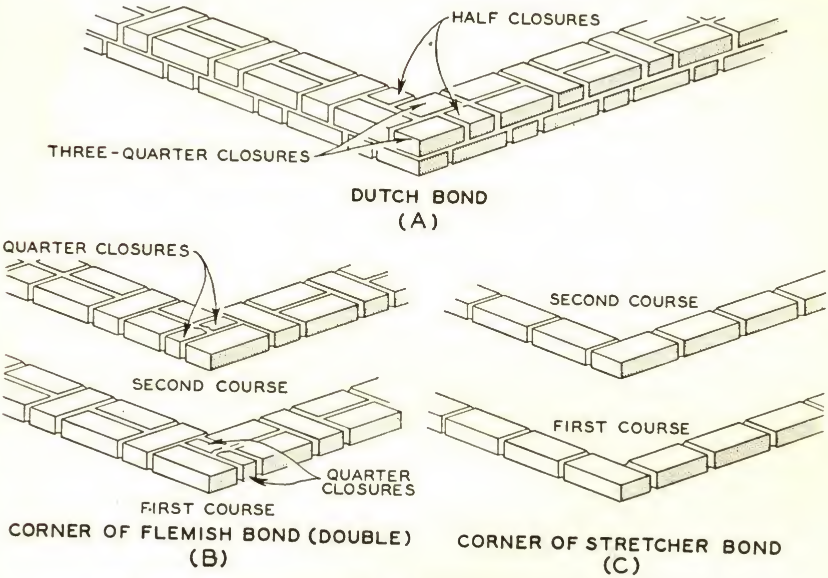


Fig. 18. Bond Details for Dutch, Stretcher, and Flemish Bond

brick veneer is supported by the concrete foundation. Note, too, the soldier and rowlock courses at the foundation level and window sill. The metal ties are generally spaced two or three bricks apart horizontally and in every fourth or fifth course. There is a space between the paper-covered sheathing and the inside surface of the bricks. This illustration also shows how bricks are laid about the window jambs and sill.

Window and Door Details. (A) and (B) of Fig. 20 show window and door details in brick walls. Note how the bonding is carried out around the window and door and how wood bricks are employed to secure the door frame.

Steel Lintel Details. When steel lintels in the forms of angle irons, etc., are used over window and door openings, the bricks must be

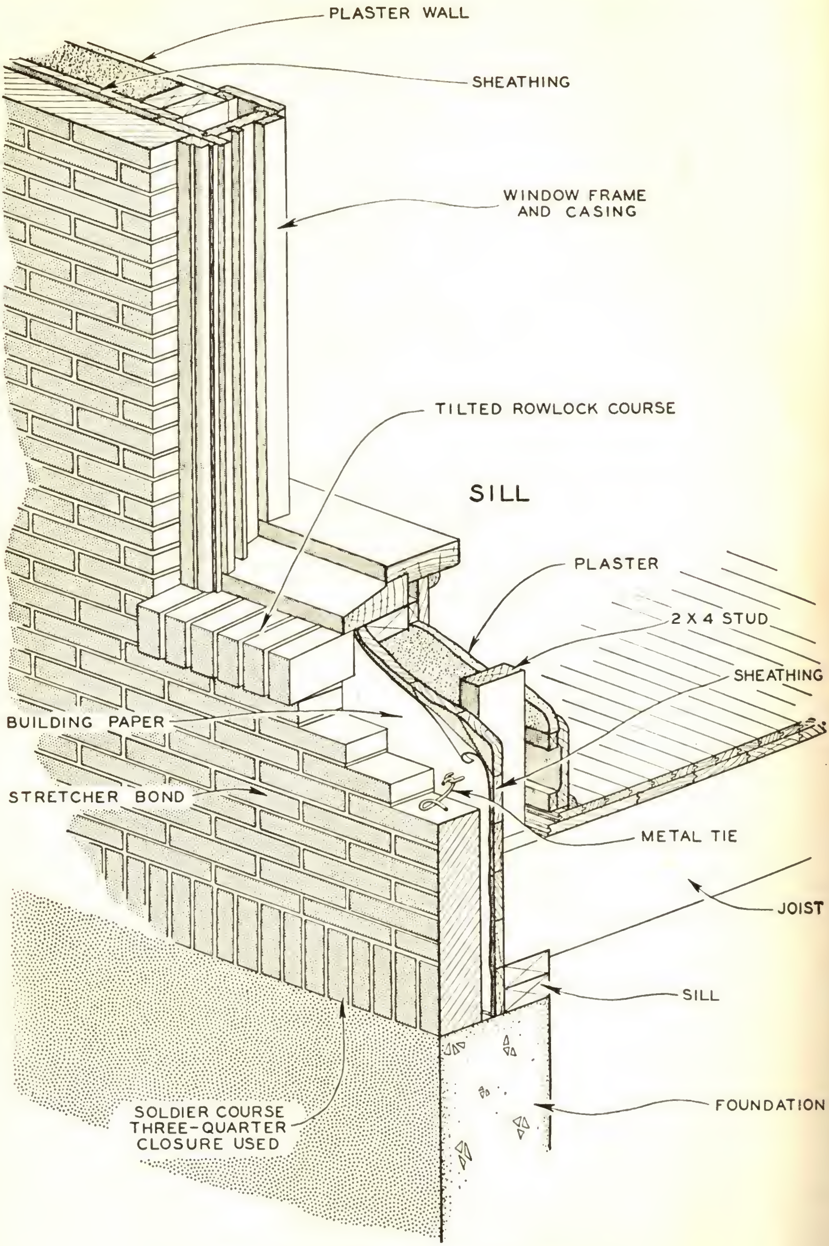
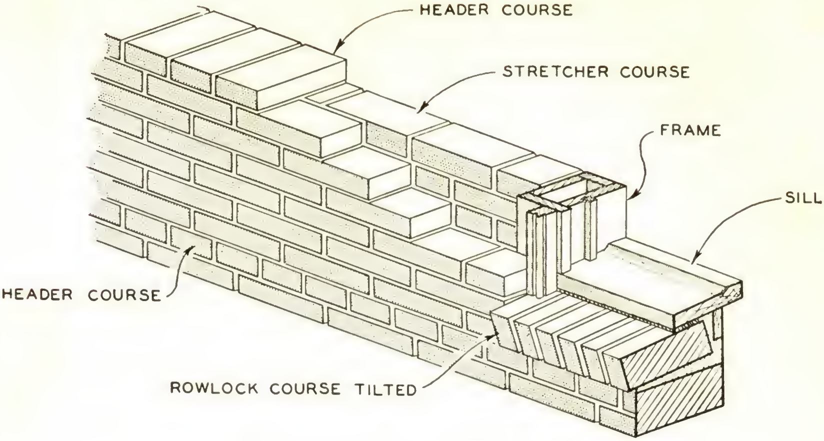
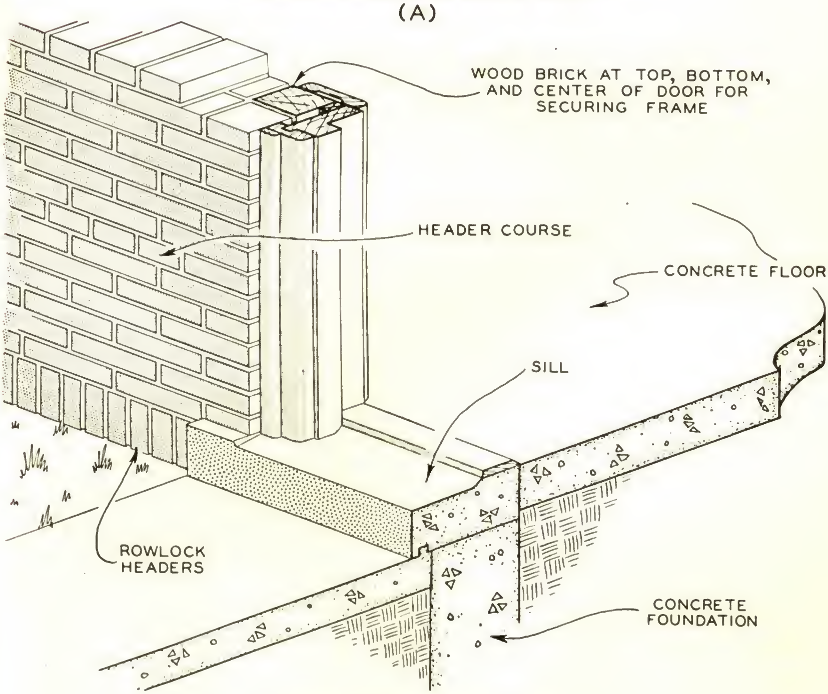


Fig. 19. Typical Brick Veneer on Frame



WINDOW FRAME IN BRICK WALL
(A)



DOOR FRAME IN BRICK WALL
(B)

Fig. 20. Window and Door Details

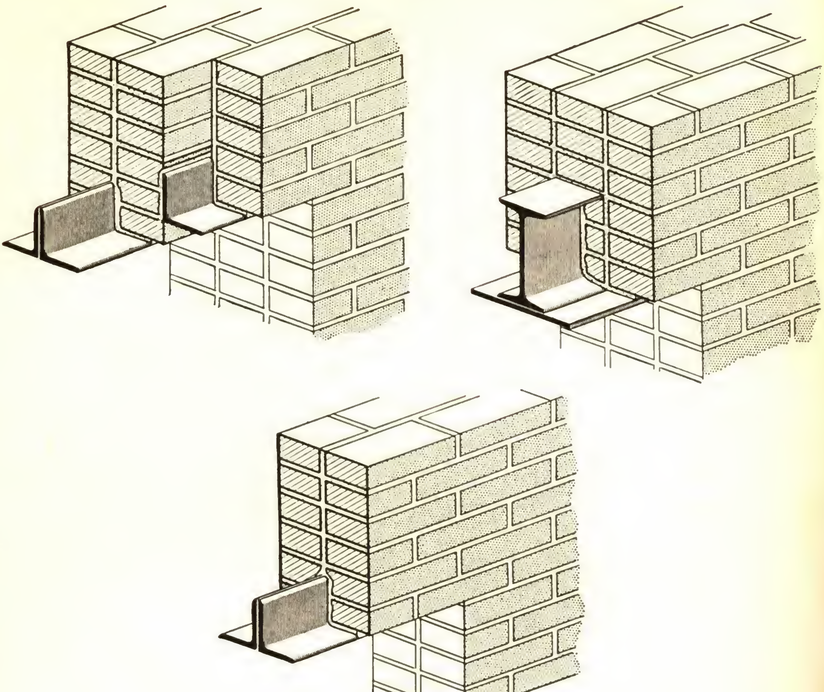


Fig. 21. Manner of Laying Brick around Steel Lintels

fitted around them carefully so as to maintain the bond and good appearance. Note in Fig. 21 that bricks are cut so as to fit snugly around the steel members. Plenty of mortar should be thrown on and around the steel as the bricks are laid around it.

Chimneys and Fireplace Details. Fig. 22 shows the plan, section, and elevation of a typical fireplace and a section of the chimney and flue lining above the fireplace.

PLAN. This view shows the arrangement of bricks around the flues and fireplace opening. Only one course is shown, but other courses are laid, in so far as possible, to break joints as is required in all good brickwork. Note that joints also must be broken in the fire brick courses.

SECTION. This view also shows the arrangement and joint-breaking required in the brickwork. Note that common bond is shown. Note, too, how partial bricks are used to fill the space back of the inclined rear tier of fire bricks. Special care should be taken to cut the various bats so that they fit nicely into the spaces they are to fill. The ash pit is narrowed down before it reaches the ash drop by means of corbeling.

ELEVATION. This view shows that a wood trim is to be used around the fireplace opening in addition to the wood mantel. Note the soldier courses across the top of the fireplace opening. The brickwork above the mantel must be solid between and around the flues. It is laid in courses in much the same manner as indicated in the plan view.

The construction of a fireplace and its chimney is perhaps one of the most difficult tasks any bricklayer could ever be called upon to do. The task requires a great deal of skill which can be acquired only by long experience. For this reason, it is not advisable for inexperienced bricklayers to attempt such a task unless they are fortunate enough to have the help and guidance of an experienced fireplace builder.

Footing and Foundation Details. Fig. 23 shows how the bricks for a footing and foundation can be bonded to provide strength and durability. The use of ample mortar to assure full mortar joints is important so that the pressure in the foundation and on the footing will be equalized. Use of a mortar made with Portland cement, lime, and sand is recommended for brickwork which is below the surface

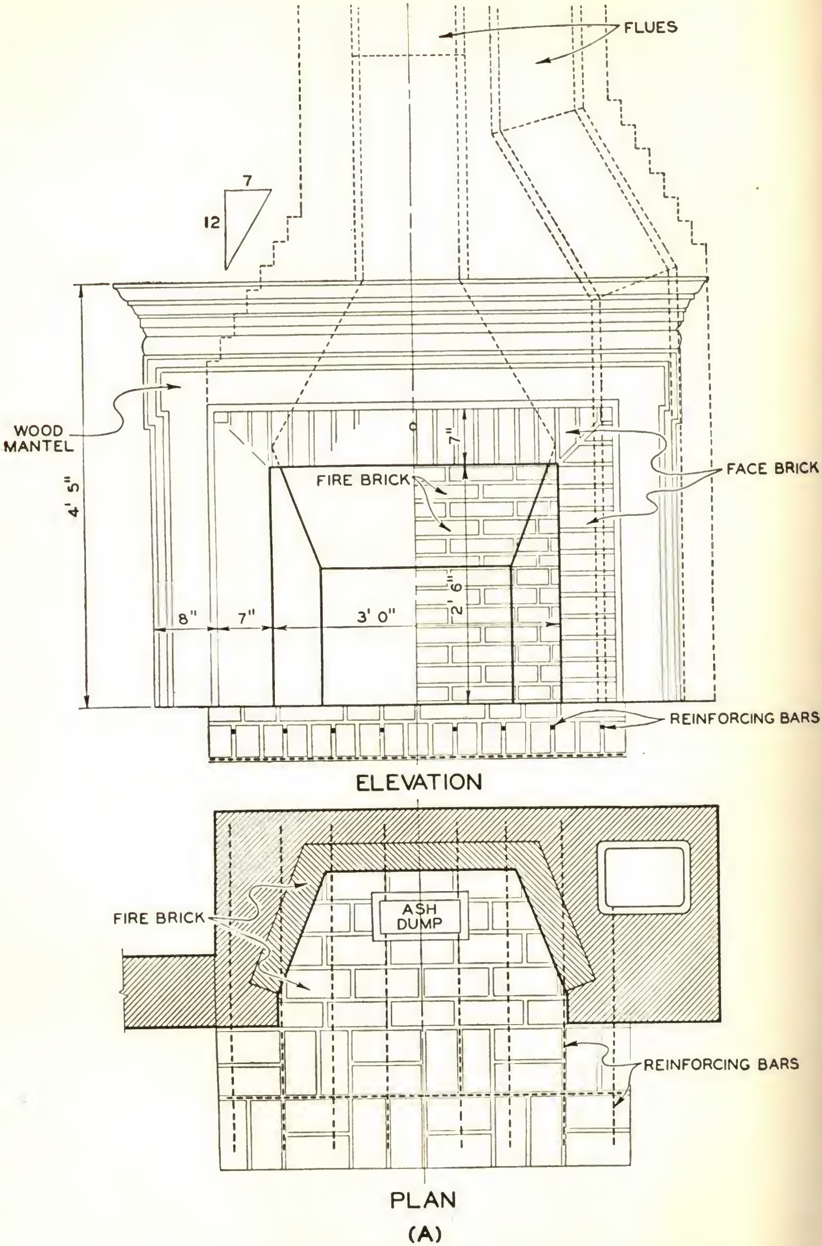


Fig. 22A. Plan and Elevation of Fireplace and Chimney Details

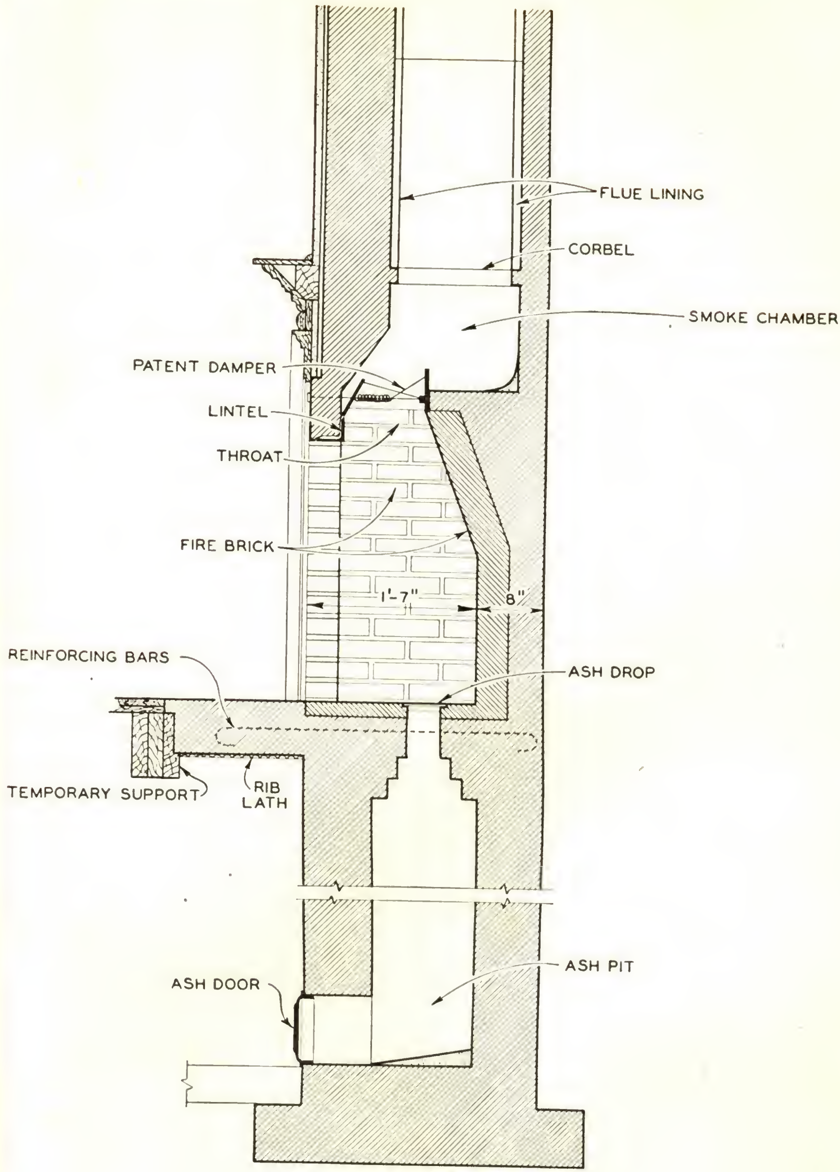


Fig. 22B. Section View of Fireplace and Chimney Details

of the ground. If the soil is wet, the exterior surface of the footing and foundation can be plastered with regular mortar to a depth of ½″ or ¾″ as a means of further waterproofing.

Corbeling Details. In many instances walls are corbeled out, that is, enlarged as a means of carrying some extra load or supporting another structural member. Sometimes the corbeling is entirely a

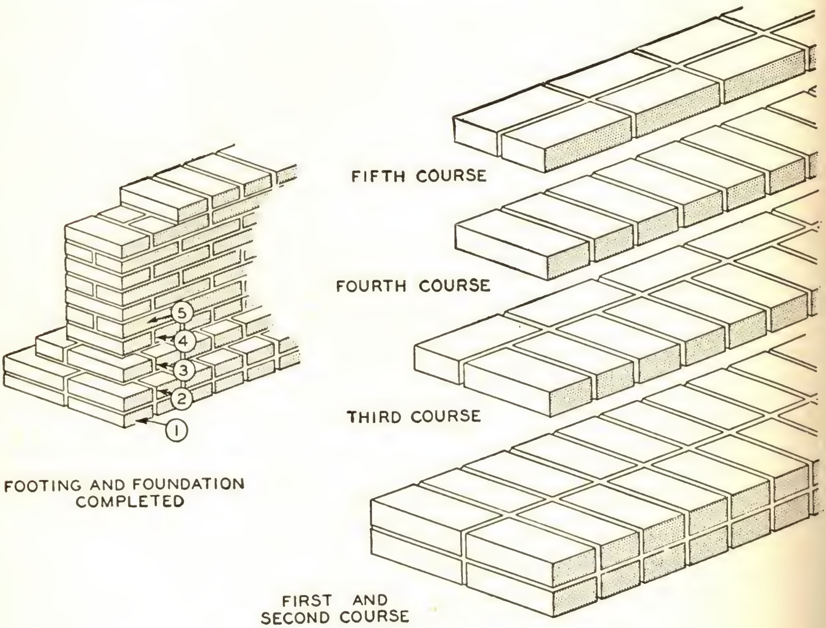


Fig. 23. Footing and Foundation Details

means of adding pattern or beauty to a wall. Chimneys are frequently corbeled to increase their wall thicknesses where they are exposed to the weather.

Fig. 24 shows the details of typical wall corbeling. Note that headers are used to a great extent and that in order to give the corbeling strength, these headers extend into the wall farther than they project beyond it. The first continuous projecting course can be stretchers but all other projecting courses should not extend beyond the under courses more than 2″ and the total projection of the corbeling should not extend more than the thickness of the wall.

Extreme care must be taken in corbeling to see that all joints are completely filled with mortar and that all bricks are level and plumb. The various bats should be cut carefully and fitted into their places.

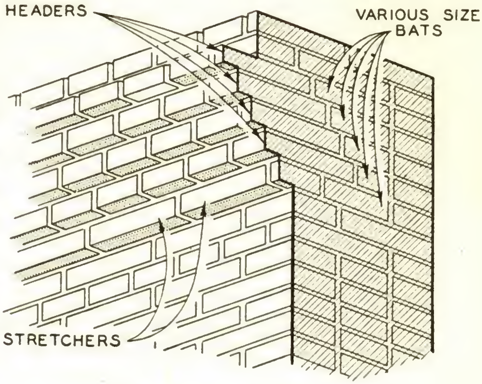


Fig. 24. Typical Corbeling

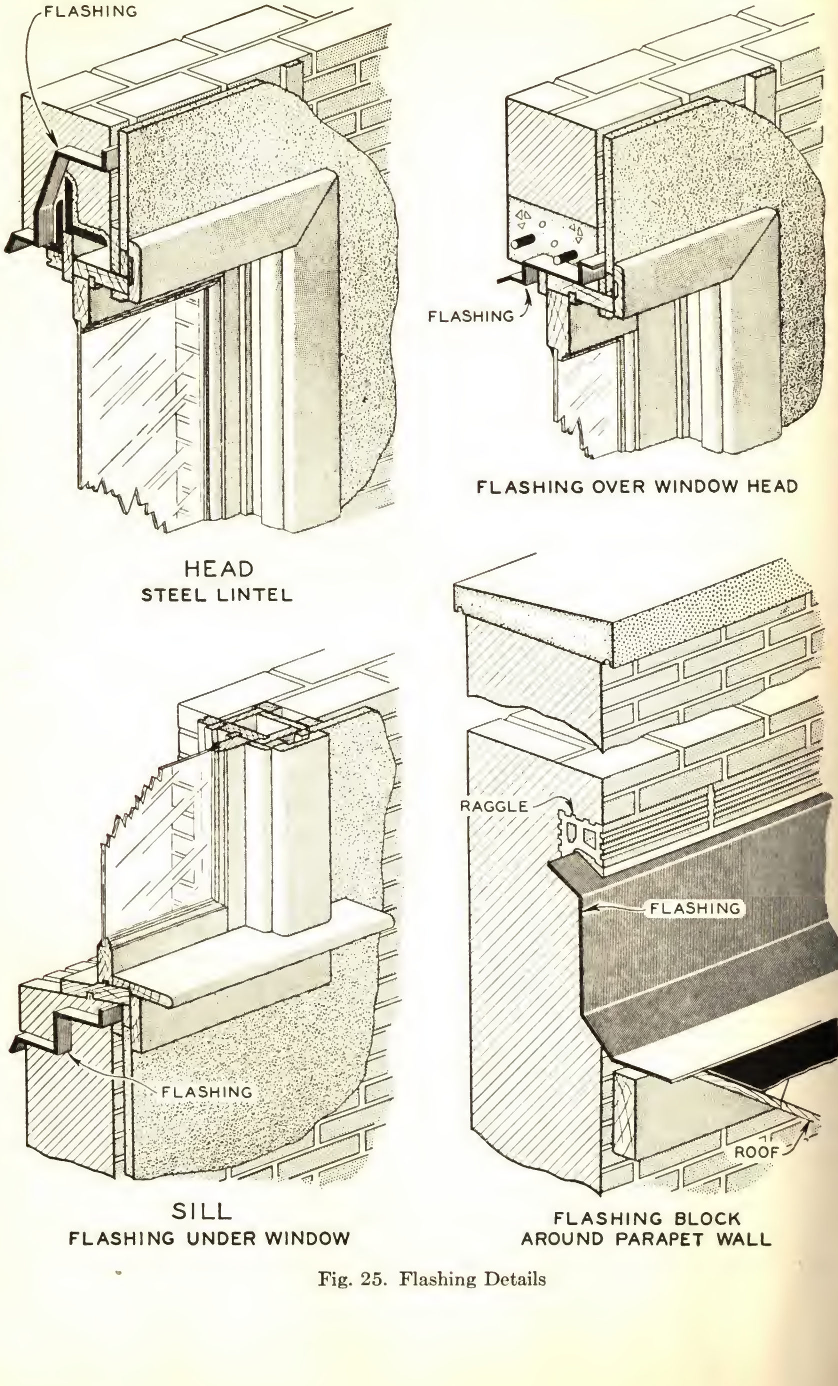
Grounds Details. When wooden or metal trim or other details are to be secured to brick walls, some means must be provided for fastening them. To accomplish this, pieces of wood take the place of one or more bricks. Note the wood bricks to which is secured the door frame in the illustration in (B) of Fig. 20. This is a typical grounds detail.

Flashing Details. Fig. 25 illustrates typical flashing details for windows and a parapet wall. The use of copper for flashing is recommended. The raggle shown in the parapet wall is a masonry unit which can be purchased ready to lay in the wall.

Lengths and Heights of Brick Courses. The lengths and heights of all walls and the widths and heights of all window and door openings in the walls should be carefully planned in order that whatever brickwork bond is used, all courses and tiers can be laid without having to use other than whole bricks in the facing tier. Fig. 26 shows an example of this.

The length and height of the wall is such that it contains exactly 15 stretchers and 41 courses. If the length of the wall had been planned a few inches longer or shorter, it would have been necessary for one stretcher to be cut, causing the bricklayer trouble and marring the appearance of the wall. An inch difference in the height of the wall would have made it necessary to make the last course out of bats.

The window and door location and sizes were planned to avoid the use of small closures. Windows and doors can be purchased in many standard sizes which makes possible exact planning.



HEAD
STEEL LINTEL

FLASHING OVER WINDOW HEAD

SILL
FLASHING UNDER WINDOW

FLASHING BLOCK
AROUND PARAPET WALL

Fig. 25. Flashing Details

Planning the length of a wall can be done once the bond has been decided upon. For example, the stretcher bond in Fig. 26 requires all stretcher courses except where headers are necessary around the corners and openings. However, a complete stretcher course, such as the second course shown in Fig. 26, can be used for the planning. Add the width of one mortar joint to the length of one stretcher. This is one unit. The length of the wall can then be made so many units long minus the width of one joint. When planning the height of a wall, add the width of one mortar joint to the height of one brick. The height of the wall can then be made any number of times that amount, minus the thickness of one joint.

Careful planning of all lengths and heights saves the bricklayer a great deal of trouble and assures a good appearance of the facing tier.

Wall Top Details. The tops of exposed parapet and fire walls should be protected by a coping of some sort to keep water from running down in the joints between bricks. Such copings can be made of tile, stone, concrete, or other impervious materials.

HOW TO LAY BRICKS

When the commonly used kinds of brick are known, when the specific uses of such brick are known, and when the typical brick masonry details are understood and can be visualized, the next logical step is to learn how this kind of masonry is actually laid. The processes or techniques involved, while not extremely difficult, do require careful study and then a great deal of actual practice. The aim of the following illustrations and explanations is to prepare the reader for the actual practice phase of his training. The following examples represent the kind of bricklaying most commonly encountered by inexperienced bricklayers.

Laying an 8" Common Bond Brick Wall. This wall of common brick has ½" joints between the units. The bricks are laid in common bond which is illustrated in (A) and (B) of Fig. 20. Note in (B) that there are six courses of stretchers, then one course of headers. In other words, there is a header course every seventh course. The positions of the bricks in a common bond wall are indicated in both (A) and (B).

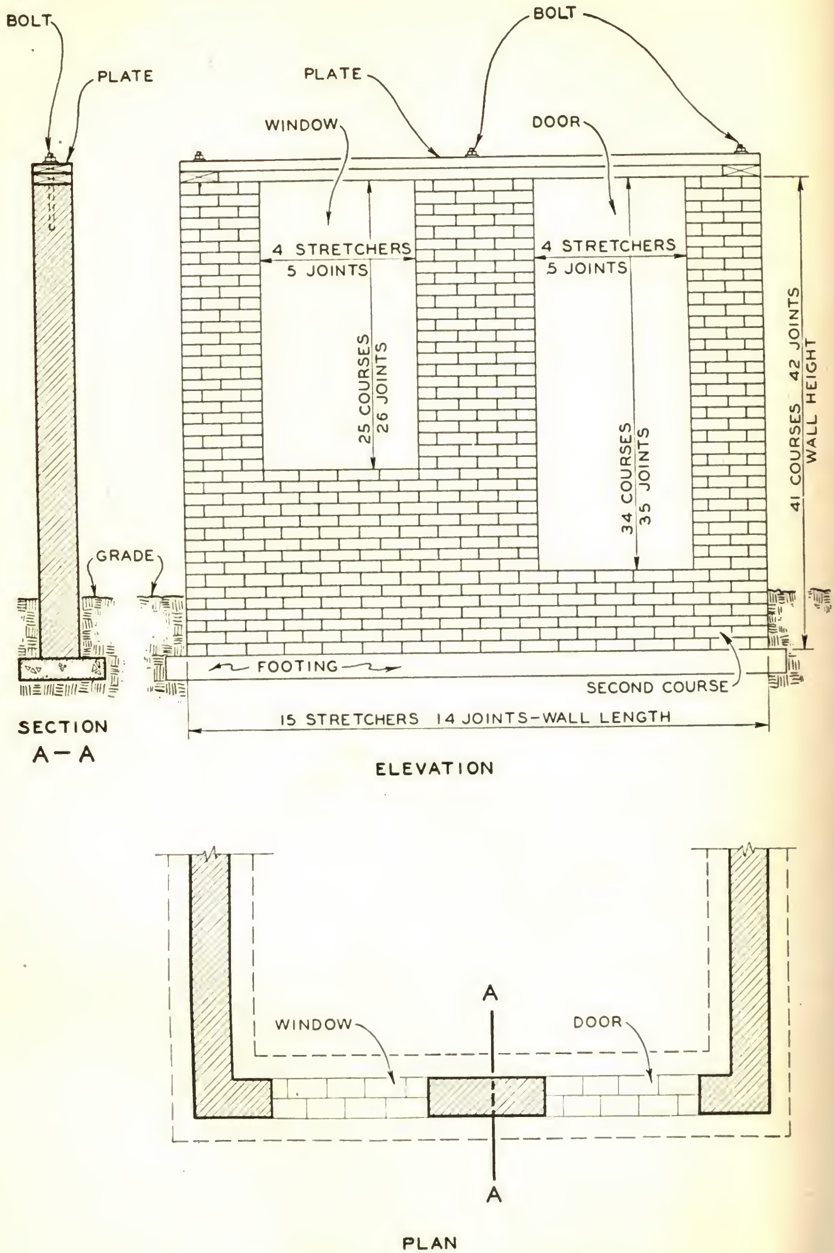


Fig. 26. Lengths and Heights of Brick Courses

Fig. 27 shows more details of an 8″ brick wall laid in common bond. The sketch at (C) illustrates a corner and shows three courses of the two tiers required. It can be seen that the first course is a header course, as is generally required. The sketch at (B) shows the details of this course. Along the lengths of walls, headers are easy to place, but at the corners, closures must be used in order to fill up the space. The use of three-quarter and quarter closures permits the filling of the corners as shown in the sketch. The second course consists of stretchers which can be laid without the use of fractional closures. This can be seen in sketch (A). The third, fourth, fifth, and sixth courses, although not shown in Fig. 27, also consist of stretchers laid so as to break joints. For example, note in sketch (C) how the corner bricks for courses two and three are alternated. This alternating of stretchers, or breaking of joints, can be seen to good advantage at (B) in Fig. 20.

In many buildings, 12″ brick walls laid in common bond are required. Fig. 28 illustrates the positions of the bricks and fractional closures in such a wall.

When masons erect brick walls, corners are laid up in advance of the wall lengths between the corners. This practice affords them the opportunity of using the corners as a guide in laying the balance of the walls. In Fig. 29, assume that the foundation shown in (A) has been poured, that it has been designed so as to fit an even number of bricks (as explained previously, relative to Fig. 20), and that it is perfectly level and ready for an 8″ common brick wall to be laid on it. The bricks at either end illustrate the corners which bricklayers always lay up before laying bricks the full length of the wall. The sketch at (B) shows one of the corners laid up and racked so that other bricks can be bonded into them when the balance of the wall is laid. Note that only the face tier is laid in these corners. It should also be noted that the corners are laid up to a height of the second header course or a distance of seven courses.

In (A) of Fig. 30 is shown a plan view of the same foundation illustrated in Fig. 29. Before the corners are started, bricklayers lay dry bricks (without mortar) along the wall to test its length in terms of bond. As shown in (A), the wall length is just right in terms of whole bricks. A stretcher course is used for such a test.

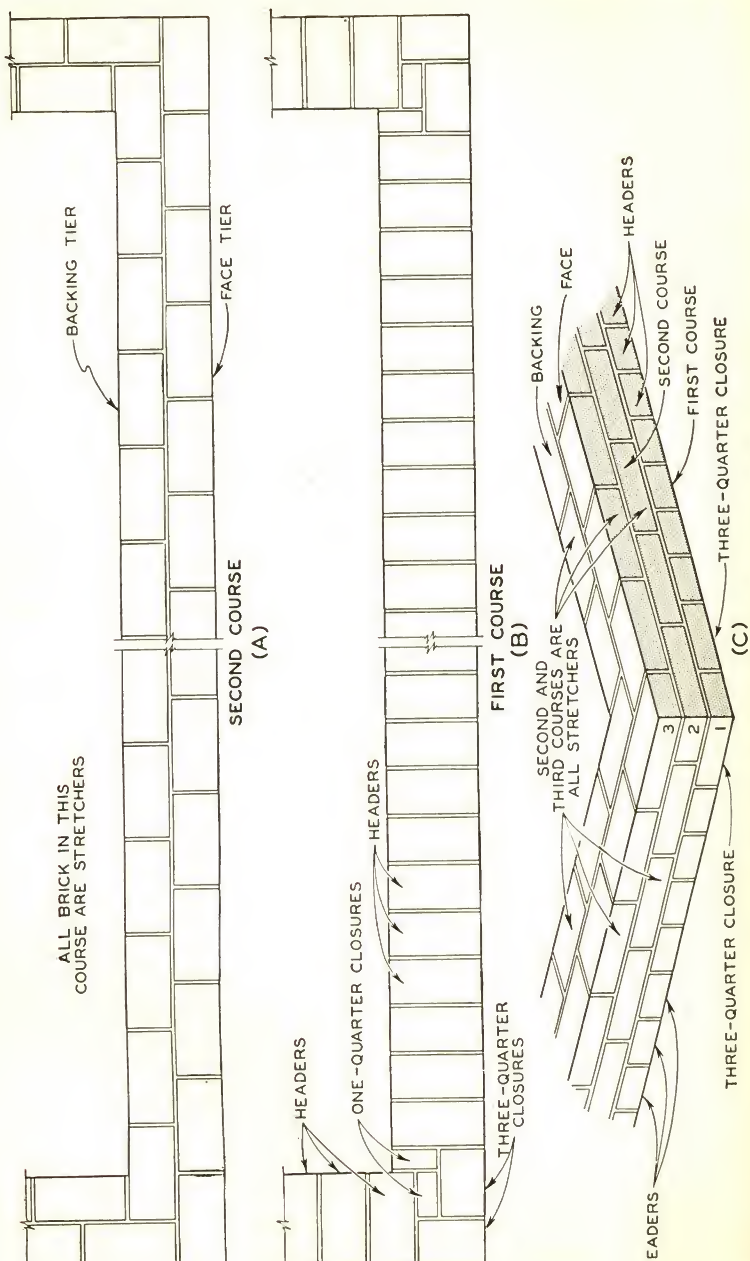


Fig. 27. Common Bond in Eight-Inch Wall

In (B) of Fig. 30 is shown the first step in laying up a corner. Mortar should be spread evenly, directly on the concrete of the foundation top and should be at least ¾″ deep.

In (C) of Fig. 30 is shown the second step. The mason cuts two bricks to make three-quarter closures as shown in (B) of Fig. 27. Closure *1* is laid on the mortar and pressed down with the hand until the joint becomes ½″ as required. The blade of the trowel is sometimes used to gently hammer the brick down into the mortar. Next, mortar should be thrown on the end of closure *2* as previously explained for head joints. This closure is then shoved gently into place up against closure *1* to form a ½″ horizontal joint with the foundation and also a ½″ vertical or head joint

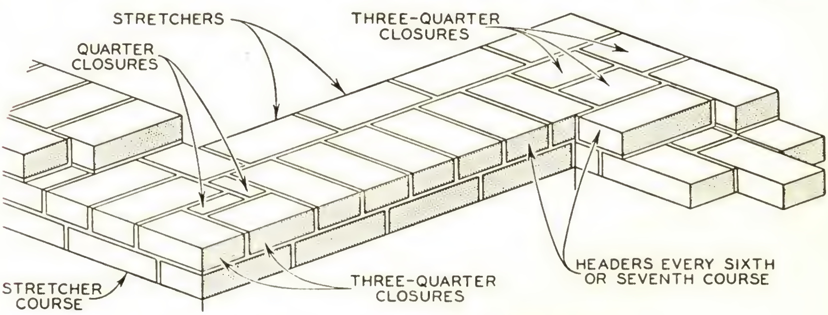


Fig. 28. Common Bond in Twelve-Inch Wall

with closure *1*. This should be done as explained for Fig. 10. Clean off the excess mortar which oozed out from the horizontal and head joints by holding the trowel as shown in Fig. 10. The level of closures *1* and *2* should be checked, using a plumb rule laid in the position of the dash lines shown in (C) of Fig. 30. If the bricks are not exactly level, they are hammered gently with the trowel until they are. The edges of both bricks also must be flush with the outside surfaces of the foundation.

In (D) of Fig. 30 is shown the third step. Brick *3* should have mortar thrown on its edge and laid as shown. Check its level using the plumb rule in the position of the dash line and make sure its end is flush with the foundation. Brick *4* is laid in the same manner and its level, etc., checked. The quarter-closures should next be cut and mortar applied to them as explained for closures relative to Figs. 13

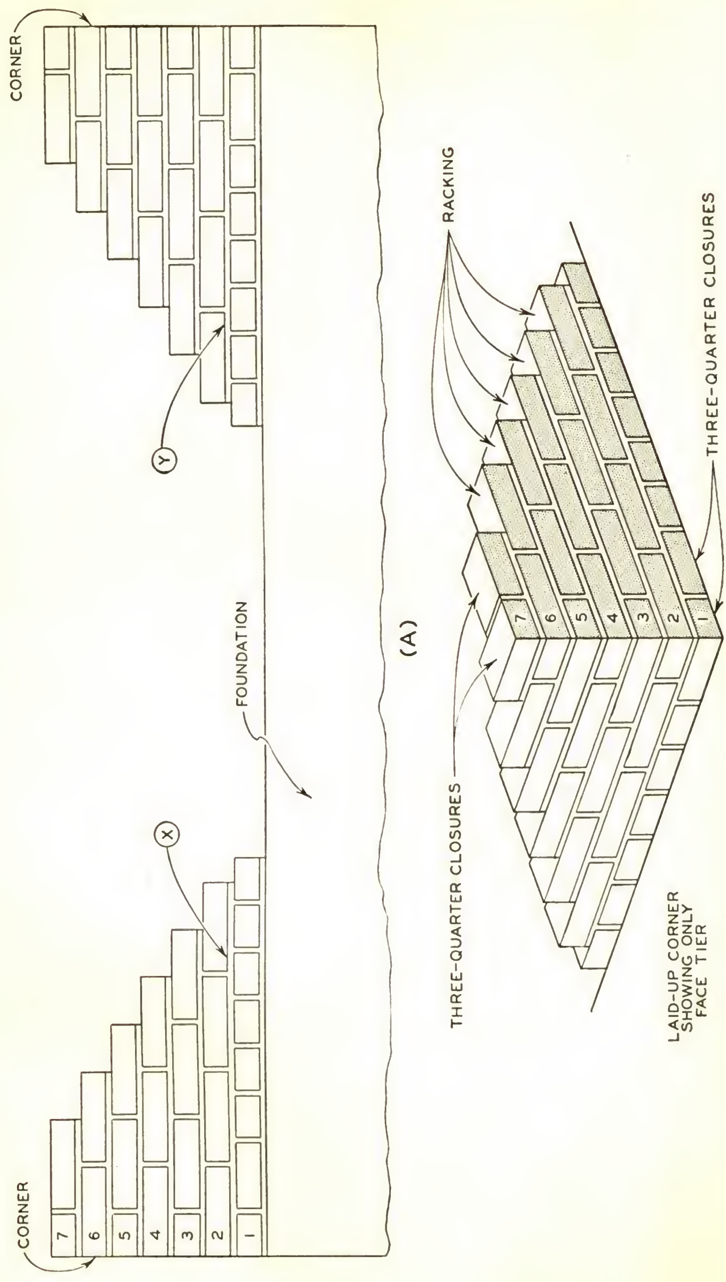


Fig. 29. Laying Corners

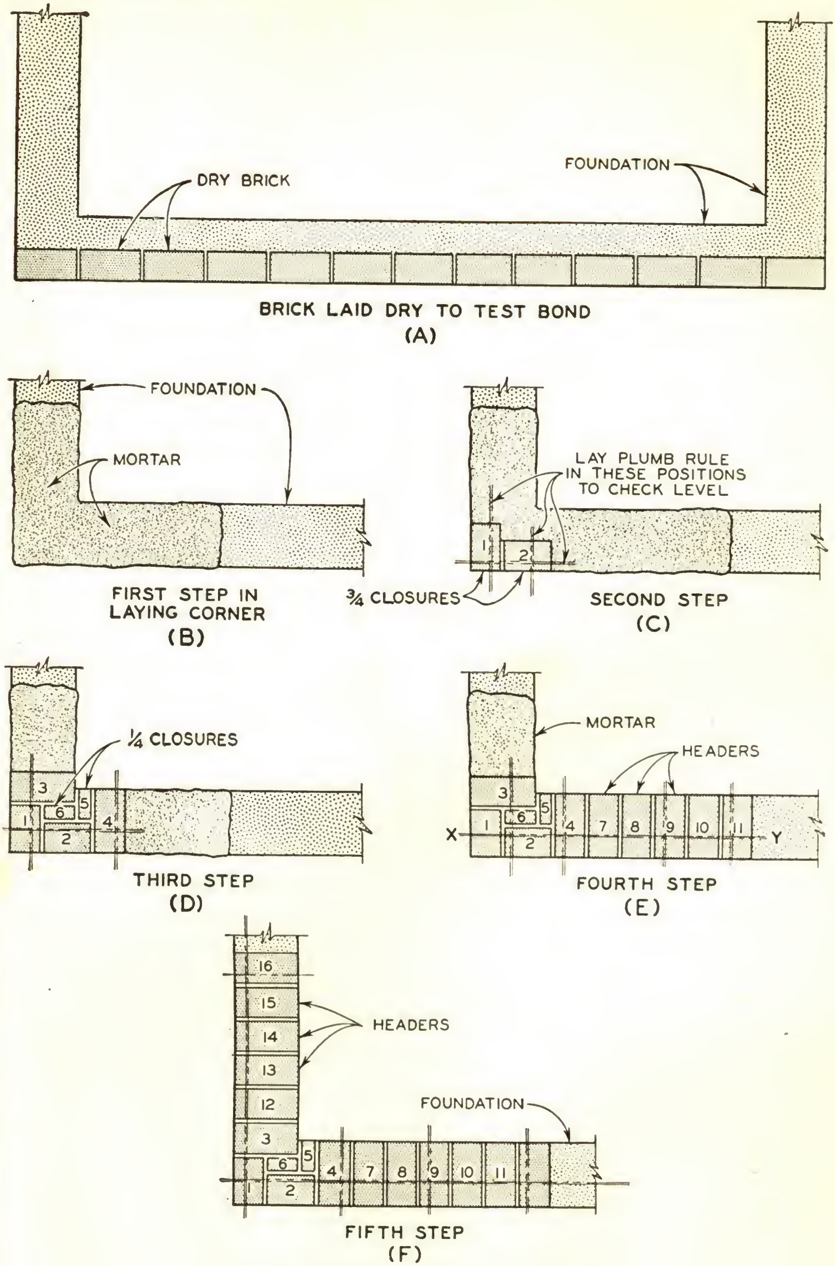


Fig. 30. Laying First Course at Corners

and 14. Remove all excess mortar and be sure that the quarter-closures do not extend above the top levels of the surrounding bricks.

In (E) of Fig. 30 is shown the fourth step. The edge of brick *7* has mortar thrown on it and is then shoved into position as shown in Fig. 12. All excess mortar is removed with the trowel. Bricks *8, 9, 10,* and *11* are laid in like manner. The level should be checked by placing the plumb rule in the position of the dash line *XY* and in the opposite direction, indicated by the second set of dash lines. The matter of flushness with the foundation also should be checked.

In (F) of Fig. 30 is shown the fifth step. Bricks *12, 13, 14, 15,* and *16* are placed in the same manner as bricks *7* through *11*.

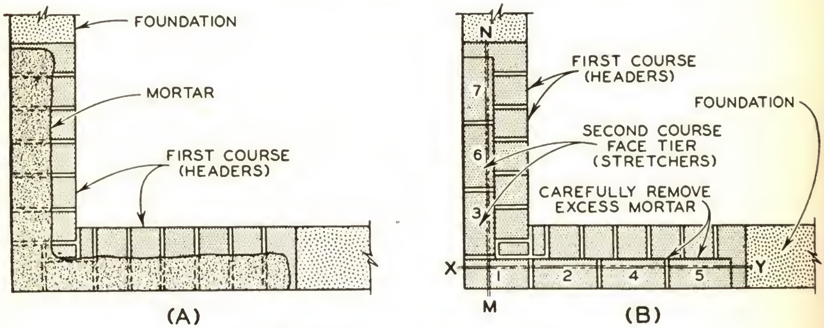


Fig. 31. Laying Second Course at Corners

The number of bricks to lay in the first course for the corners can be determined from a sketch such as shown in (B) of Fig. 29.

The second course for the corner, as shown in (B) and (A) of Figs. 29 and 27 respectively, should be composed of stretchers. But only the facing tier should be laid at this stage of the wall construction.

In (A) of Fig. 31 is shown the first step in laying the second course of stretchers. Mortar should be spread over the first course to a depth of at least ¾ inch. The furrow in the mortar, as explained for bed joints and as illustrated in Fig. 9, should be shallow. Brick *1* should be laid on the mortar and gently shoved or hammered down until the mortar joint is ½ inch. Mortar should be thrown on the end of brick *2* and the brick shoved into position. Remove excess mortar as shown in Fig. 10. The joint should be checked for thickness. Bricks *3, 4, 5, 6,* and *7* should be laid in the same manner. Next, the level and plumbness should be checked. The check for level

is made by placing the plumb rule in the positions of dash lines XY and MN. The plumb check is made by placing the plumb rule in a vertical position against the foundation and bricks at several points.

Note: The number of bricks necessary in the second course for the corners can be determined from the sketch shown in (B) of Fig. 29.

The balance of the courses, see (B) of Fig. 29, are laid in the same manner. Care must be exercised in constantly checking the level, and after the first few courses, the plumbness of the rising corner. This is especially important because the wall between corners is laid using the corners as a guide. If the courses are not plumb, the bricks must be moved in or out until the plumb check is perfect. It is not

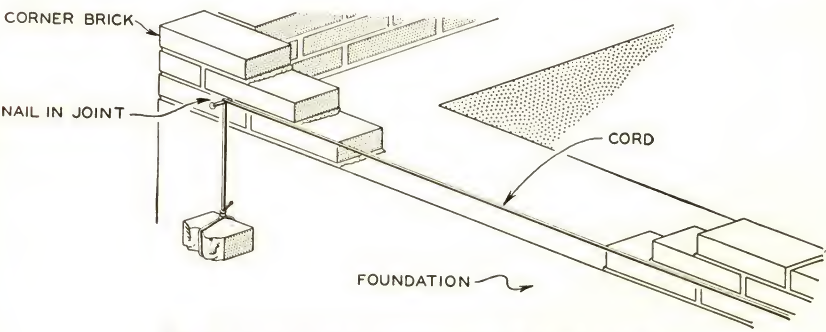


Fig. 32. Cord Used as Guide in Laying Every Course

good practice to move bricks once they have been laid, so special care should be taken to lay the corner plumb as it progresses.

The joints should be well pointed before the mortar has set. The outside joints are finished using a pointing tool. The inside joints can be finished flush with the trowel.

The foregoing procedure should be followed in laying up all corners.

In order to lay the face tier bricks along the wall between the corners, a cord should be stretched to serve as a guide for each course. Note Fig. 32. To place the cord in proper position for laying the first course between corners, drive nails into mortar joints as shown by X and Y in (A) of Fig. 29. The cord is wound around these nails, as shown in Fig. 32, with a weight to hold the cord at each nail. As shown in this illustration, the cord should not quite touch the outer corner of the corner brick. See cords in Fig. 12.

With the cord in place between nails X and Y in (A) of Fig. 29, the first, or header, course can be laid between the two corners. The joints are all cross joints and the mortar should be applied and the bricks laid as previously explained for such joints and as illustrated in Fig. 12. As each brick is laid, its outer and upper corner should not quite touch the cord. The cord thus serves as a guide in keeping all bricks level and the wall plumb. For the second course between corners, the cord should be moved up one course. This course consists of stretchers which should have mortar applied to them as previously explained relative to bed and head joints and be laid as explained for Fig. 13.

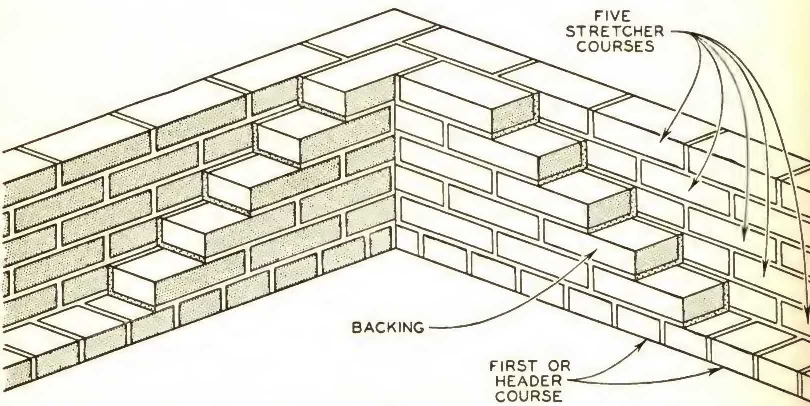


Fig. 33. Backing for Corner of Eight-Inch Brick Wall

The face joints should be tool pointed and the inner joints troweled smooth prior to the time the mortar sets.

When the face tier for two corners and the intervening wall have been laid up to the height of the second header course (six courses as shown in (A) of Fig. 29), the backing tier is laid. It is best to lay the backing bricks first for the two corners, as shown in Fig. 33, and to lay the balance of the backing after that. It is not necessary to use a cord for the backing except for 12″ walls.

Apply mortar to backing bricks and lay them as explained for Fig. 11. Closures for backing tier courses should be laid as previously explained.

When the backing for the first wall is complete up to header

height, another corner, adjacent to one of the corners already completed, can be laid up and the same procedure followed.

When all walls have been completed to the second header height, corners are again laid up to the third header height and the same process repeated. This general procedure is followed until the proper total height of the wall has been reached. Provisions for window and door openings are discussed in advanced examples.

Laying an 8" Common Bond Wall with Common and Face Brick. This type of wall is laid following exactly the same procedure just explained for a common bond wall in common brick, except for the following differences:

First, the face tier is laid using face bricks.

Second, the headers are all laid using face brick.

Third, the backing stretcher courses are laid using common brick.

Fourth, face brick generally require much more careful joint pointing.

Fifth, there may be some backing tier joint variation if the face brick tier must be laid using very thin joints. In such cases, bricklayers sometimes use one less course of bricks in the backing tier with much thicker joints. The main object is to make both tiers even at every header course. The joint thickness required can be determined by trial.

Laying Window Openings in 8" Common Bond Brick Walls. If one or more windows are required in a brick wall, the bricklayer must plan for them in advance in order that one course of bricks will be at exactly the right height above the foundation for the window sills. Note the window in the wall shown in (A) of Fig. 20. Not counting the rowlock headers, there were exactly 12 courses up to the bottom level of the sill. By measuring the vertical distances window sills must be above foundations, bricklayers can determine how many courses that distance is equal to. This can be done by measuring such a distance on a wall already laid and then counting the courses. Architects generally consider brick courses when they determine window location dimensions, but it is wise for bricklayers to check for their own convenience.

When a brick wall has been laid up to sill height, the rowlock sill, shown in (A) of Fig. 20, is laid. Note that this rowlock course

should be sharply pitched and should take up vertical space equivalent to two courses. When laying the rowlock course, ample mortar should be used under and between bricks. The surface joints must be very carefully tooled to make them waterproof.

After the rowlock sill has set, the window frame, indicated in (A) of Fig. 20, is placed on the sill and temporarily supported by wood braces. Once the window frame is in place, the bricklayer's next concern is to lay up the surrounding wall so that a course of brick near the top of the frame comes at a level not more than ¼″ higher than the frame. To accomplish this, he marks with a pencil the position of the top course on both sides of the frame. Below these marks, he makes other marks indicating where each header course should be. Sometimes mortar joints have to be varied a little in order to bring header courses to the marks on the frame.

Bricks are laid on both sides of the frame using the cord stretched across the frame opening as previously explained. If window locations have been well planned by the architect, the bond in the face tier will not be disturbed. In other cases, bricks of the face tier may have to be cut.

When the wall has been built up to the height of the frame, mortar is applied about ½″ deep to the top of the frame and to the wall on both sides of the frame. Steel lintels are then placed over the window opening and bedded in the mortar. Once the two pieces of the lintel (see *X* in Fig. 21) are in place the wall is continued on above them. Note in Fig. 21 how the bricks are cut so they will fit around the lintels.

Laying Door Openings in 8″ Common Bond Brick Walls. Practically the same procedure is followed in laying bricks around door openings as explained for window openings.

Note the wood brick grounds shown in (B) of Fig. 20. These pieces of wood are cut to the size of a half-closure and then laid into the various courses, using mortar the same as for the clay bricks. When the wall is complete and has set, the door frame is secured to the wood brick by means of nails or screws.

Laying a 4″ Brick Veneer Wall on a Wood Frame. Brick veneer, as shown in Fig. 19, generally consists of one tier with the bricks laid in stretcher bond.

The laying of brick veneer follows closely the procedure explained for 8″ walls except that no backing or headers are used and metal ties are employed to secure the veneer to the frame wall. Corners should be laid up seven or eight courses high and a cord used to guide the laying of intervening courses. The window frames are already in place when the veneer is started so the bricklayer can judge easily where the last course before the rowlock sill must be in terms of distance above the foundation.

In Fig. 19, the soldier course is composed of three-quarter closures or, if it is desirable, this course can be laid using specially made bricks about 5″ or 6″ long. Fig. 34 shows how queen closures can be used at the corners so as not to break the appearance.

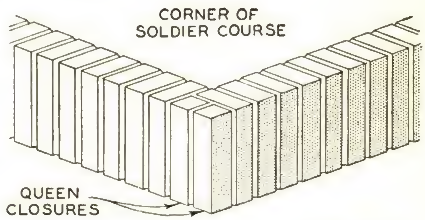


Fig. 34. Corner of Brick Veneer Soldier Course Showing Method of Placing Brick

The soldier course is laid in much the same manner as explained for Fig. 30 in (A), (B), (C), etc. Following this, the courses of stretchers are laid as was explained for (A) and (B) in Fig. 31.

Metal ties must be installed as the corners and intervening wall courses are laid, spaced as previously explained. Care should be taken to nail the ties in such positions that the nails will penetrate the studs and not just the sheathing. This will insure their holding firmly. Laying bricks around and over door and window openings is carried on as described for the 8″ wall. Joints must be carefully tooled so as to add to the good appearance of the wall.

Laying Pilasters. When foundations must support a heavily loaded beam end, it is wise to strengthen the foundation by means of a brick pilaster laid up against it. Such a situation is illustrated in (A) of Fig. 35. Such supports or pilasters may be of any size depending upon the load but those shown in (B) and (C) are typical. Pilasters must be supported by footings made of concrete or brick.

The pilaster at (B), being slightly greater than 8″ x 12″ in section, is bonded using three alternate courses as shown. The pilaster at (C), being slightly greater than 4″ x 8″ in section, has only two alternate bonding courses.

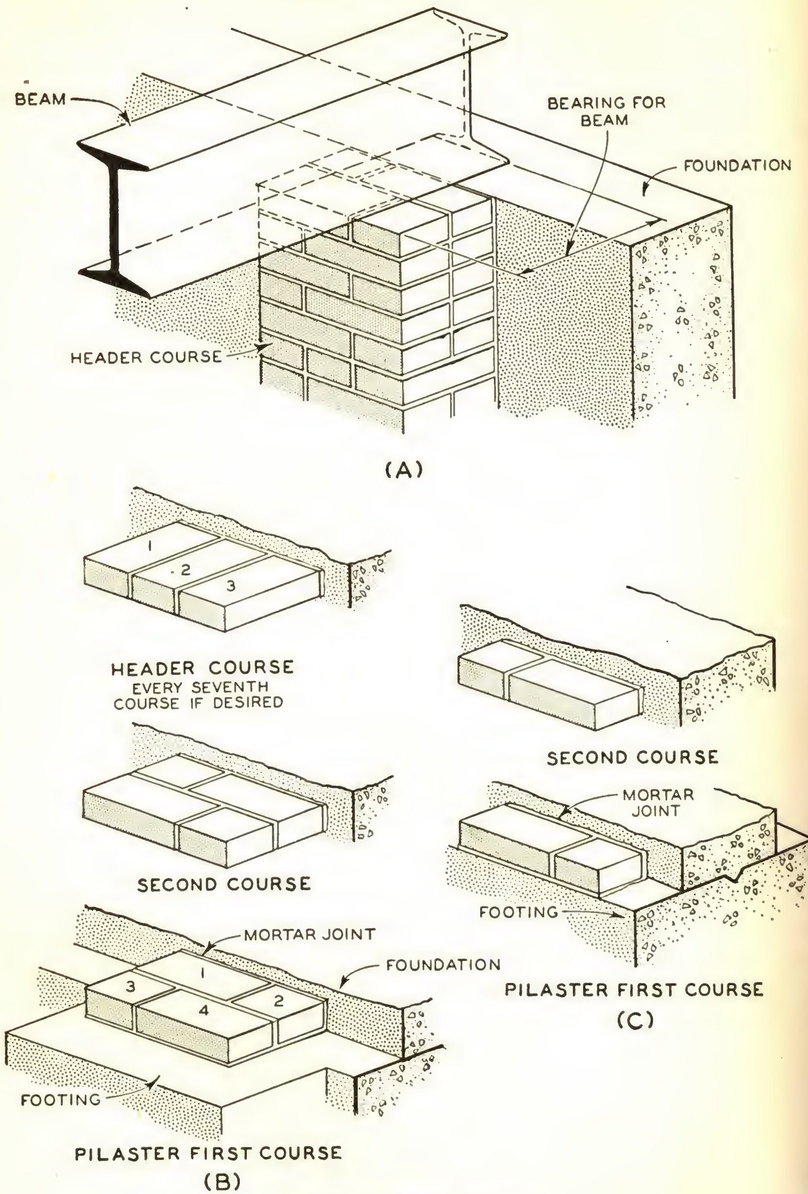


Fig. 35. Typical Pilasters

The first step in the laying up of a pilaster such as the one shown at (B) is to spread mortar evenly about ¾″ deep on the footing. Then throw ample mortar on one edge of brick *1* and shove or gently hammer it with the trowel into place, making a ½″ joint between it and the foundation and between it and the footing. Lay half-brick *2* in the same manner. Then throw mortar on one edge of half-brick *3* and shove it into position. For brick *4*, it is necessary to throw mortar on one end and one edge before shoving it into position. Remove all excess mortar and then test the level with the plumb rule.

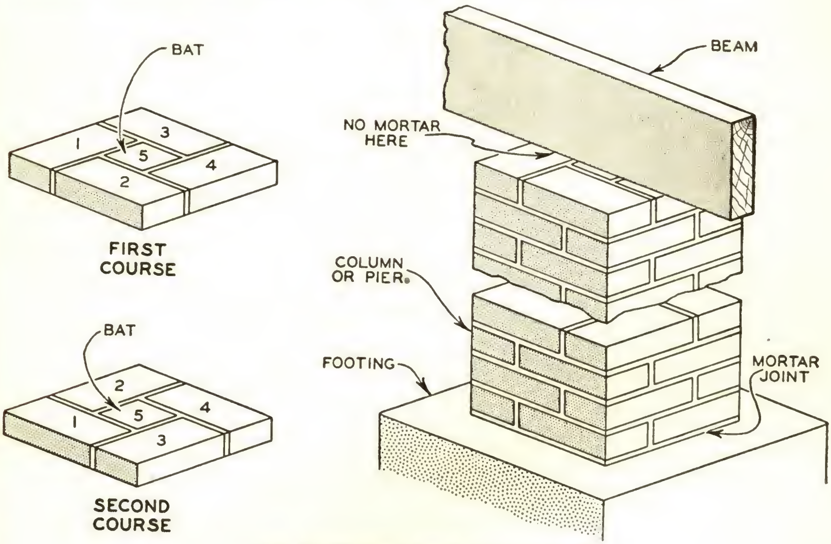


Fig. 36. Typical Brick Column or Pier

The second course is laid in much the same manner but with the bond variations shown. It is essential to have an ample bed of mortar.

To lay the third or header course, spread mortar over the second course, then throw mortar on one end of brick *1* and shove it into place. For bricks *2* and *3*, throw mortar on one end and one edge before shoving them into place. Check their level with plumb rule.

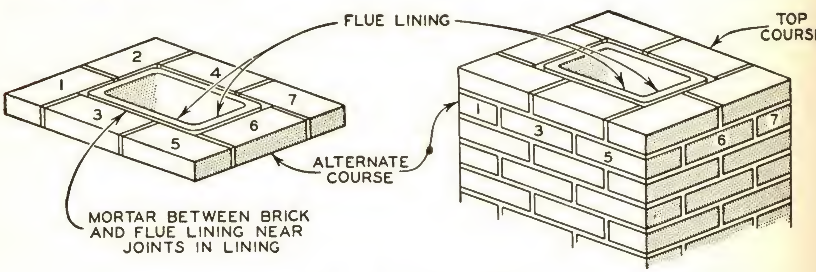
Continue courses *1*, *2*, and *3* in alternate manner to the top of the pilaster. Use the plumb rule to plumb the pilaster frequently and make any corrections necessary. A load-bearing masonry detail like this must be perfectly erect.

The exact height of the pilaster can be governed by varying some

of the mortar joints. The top should be left without mortar except that between the joints. The joints should be pointed to taste. Loads can be applied to pilasters after two days.

Laying Columns. Brick columns, such as shown in Fig. 36, are employed frequently to support wood or steel beams. Typical bonding for a 12″ x 12″ column is shown by the alternate first and second courses. The center bat is necessary in every course.

The bricks are laid in much the same manner as explained for pilasters. The center bat should have mortar thrown on all four sides as it is laid in each course. Lay the bricks in the numerical order shown. Level every course and check the erectness frequently because columns, too, must be perfectly erect. Loads can be applied to columns two days after they are laid.



Fig, 37. Typical Chimney

Laying a Simple Chimney. Fig. 37 shows the alternate courses for a simple, flue-lined, brick chimney.

When the exact location of the chimney has been determined, it is wise to lay out its exact outline on the footing with chalk or a pencil. The steel square should be used to make certain all corners are 90°.

To lay the first course, spread mortar evenly around the lines which indicate the chimney position on the footing. Shove brick *1* into place, making a ½″ bed joint. Then throw mortar on the end of brick *2* and shove it into place. Gently hammer it down with the blade of the trowel if necessary. Lay the other five bricks, being sure to throw mortar on properly. Clean off excess mortar and use the plumb rule to level the entire course. Apply bed mortar over the first course and, being sure to throw mortar on all bricks properly, lay the second or alternate course. This course also must be checked carefully for level and plumb. When several courses have been laid,

the first section of flue lining can be lowered so that it rests on the footing.

The laying of courses is continued until the wall of the chimney is about two courses below the top of the first section of flue lining. From two courses below to two courses above the joint in flue-lining sections, mortar should be applied between the inside edges of the bricks and the sides of the flue lining. This practice helps make the chimney more fireproof.

When height of the chimney wall reaches the top of the first section of flue lining, mortar is carefully applied around the edges of the flue-lining top and another flue lining carefully laid in place. The wall laying is then continued with care being taken to put mortar between the bricks and the flue lining for two courses above and two courses below the flue-lining joint. This method of placing flue linings requires more care and is a little slower but makes for an absolutely fireproof chimney which is otherwise impossible.

The balance of the chimney is laid up in the same manner. Frequent checking to make certain the chimney is absolutely plumb is necessary. The formwork of the building in which the chimney is located will help to keep the chimney erect, too. The joints should be pointed before the mortar sets.

Laying Bricks around Joist Bearings in Brick Walls. As brick walls are being laid, the bricklayer usually makes what is called a story pole to use in helping him lay up the wall to the exact height where second-floor joists will have their bearing in the wall. The story pole generally is equal in length to the distance from the rough flooring of the first floor to the height where joist bearing is necessary. With the aid of such a pole and by varying mortar joints, bricklayers can easily bring certain courses to required heights. When brick walls have reached the joist-bearing heights, carpenters usually place the joists in their proper positions. The laying of the wall is then continued.

Joists extend at least 4″ into a wall. Thus, bricks must be laid around them. This is accomplished by cutting the bricks but without changing the bonding. In other words, if a joist takes some of the space which would otherwise be occupied by a stretcher, enough of the stretcher is cut off so that the remaining part can be laid in the available space in the wall. This is illustrated by the sketches in Fig. 21

showing the fitting of bricks and bats around lintels. When filling the brickwork around joists, care should be taken to fit the trimmed or cut bricks no more than enough to allow them to fit into position. The use of small, irregularly-shaped pieces of bricks between the joists is not good practice.

MAINTENANCE OF BRICK WALLS

Repointing Old Brickwork. Old brick walls which have been exposed to the weather for many years may need repointing as a means of improving their appearance and to make them more watertight and airtight. This is necessary because the original mortar in the joints weathers away due to the effects of rain, wind, heat, and freezing. Repointing is not difficult.

The first step in repointing is to clean out the old mortar in the joints to a depth of at least ⅛ inch. The old mortar can be loosened with the small end of the hammer, then scraped out with pointing tools made for that purpose. Also, a thin chisel can be used with a hammer to loosen and remove the old mortar to the desired depth. A stiff brush should be used to remove all dust or remaining loose particles of old mortar.

New mortar is applied to the joints using one of the many special tools made for such purposes. In general, a long, thin trowel is employed whose blade is from ¼″ to ½″ wide. Some bricklayers wet the joints before applying the new mortar. Before the mortar sets, it should be pointed using a regular pointing tool. Sometimes the mortar is applied with very small trowels so that the new mortar is flush with the bricks and is then brushed with a semi-stiff brush just before it sets. The finishing method is largely a matter of taste. The important item is to force the mortar into the joint so that it completely fills the cavity and sticks in place. Repointing an old wall adds surprising new beauty to it.

Exposed chimneys are apt to need repointing much more frequently than walls. This is because chimneys are alternately hot and cold and because they are generally more exposed to beating rain, wind, and freezing than most walls. It is wise to inspect chimneys, especially near their tops and at the point where they emerge from roofs, every few years. Chimneys which do not have flue linings should be checked

yearly and frequently repointed due to their becoming causes for roof fires when mortar joints are loose.

The process of repointing chimneys is the same as explained for walls.

Painting Brickwork. Brickwork may be painted without damage but certainly without improving it any. Whether a wall, for example, is to be painted or not depends entirely upon the owner's taste. When brick walls are painted, there is the additional cost plus maintenance to be considered. Repainting is frequently necessary because painted bricks generally spall, causing unsightly appearance.

There is no appreciable proof that painted brick walls are superior to unpainted walls from the standpoint of insulation beyond the fact that if a wall is painted with a light color and frequently repainted, it will reflect heat.

Bricks which are to be painted should be hard-burned and more resistant to freezing in the presence of moisture than ordinary bricks, in order to prevent spalling and continued unsightly appearance.

In general, well-laid brick walls can be made attractive enough so as not to need painting as a means of adding to their beauty.

Efflorescence. Efflorescence is a light powder or crystallization deposited on the surface of brickwork or concrete and is the result of the evaporation of water carrying water soluble salts. There are two general conditions necessary to produce efflorescence: First, soluble salts present in the wall materials; and second, moisture to carry these salts to the surface of the bricks. In general, good bricks contain but little of the soluble salts which produce efflorescence. The mortars and plasters are more frequently the sources of the salts.

Since moisture is necessary to carry soluble salts to the surface of bricks, efflorescence is evidence that there is faulty construction. Wet walls may be due to defective flashings, gutters, and down-spouts, faulty copings, or improperly filled mortar joints. The use of frozen bricks at the time of construction also adds moisture to walls. Any repairable items should be taken care of, including repointing of the joints.

Efflorescence can be prevented by the use of good materials in proper condition and especially by good workmanship in regard to the proper amounts of mortar in all joints. Unless joints are completely

filled, moisture is almost certain to enter walls and very possibly cause efflorescence.

Efflorescence can be removed sometimes by scrubbing the wall with water and a stiff brush. If this treatment is unsuccessful, wet the wall thoroughly with water, then scrub with water containing a 10 per cent solution of muriatic (hydrochloric) acid. Immediately after, the wall should be thoroughly rinsed with plain water. It is sometimes desirable to follow this rinse with water containing approximately 5 per cent of household ammonia.

Cleaning Brickwork. There are many uncertainties about the cleaning of any brickwork which make the job one for men experienced in the process. Sand blasting frequently is employed as is the steam or steam- and water-jet process.

The sand blasting method actually removes a thin layer from the surface of the bricks. This destroys the original texture of the brick and leaves the surface with a coarse texture which may or may not be pleasing. Also, it is necessary frequently to repoint the joints after sand blasting.

The steam or steam- and-hot-water-jet process successfully removes most of the soot and dirt. It is most successful when used for fine-textured, hard-burned bricks.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. How brick veneer should be secured to the frame wall for which it acts as facing?

Answer. By the use of metal ties spaced about three bricks apart horizontally and in about every third course.

2. How parapet wall flashing is attached to the wall?

Answer. By means of a raggle.

3. Why headers should be used to a large extent when corbeling?

Answer. Because they extend well into the wall and thus add strength to the corbeling.

4. What three types of masonry materials, aside from mortar, are used in fireplace and chimney construction?

Answer. Brick, fire brick, and flue lining.

5. How bricks are made to fit snugly around steel lintels?

Answer. By cutting the bricks to required shape.

6. How door frames, for example, are secured to brick walls?

Answer. By the use of wood grounds which are embedded in the brickwork.

7. How big a quarter-closure is when compared to a queen closure?

Answer. Half as large as the queen closure.

8. If bed mortar in stringer courses should be furrowed and if so, how deep the furrows should be?

Answer. The furrows should be very shallow and their depth should be just enough to be apparent.

9. How the facing tier of a solid 12″ or 13″ brick wall laid in stretcher bond is secured to the wall?

Answer. By means of the mortar and metal ties which are embedded in the mortar.

10. What kind of bonding is usually used for brick walls?

Answer. Common bond.

11. Why bonding is necessary in walls?

Answer. To make the wall a solid mass and thus stronger and more durable.

12. If it is always possible to make ¼″ mortar joints in tiers being laid with bricks made by the stiff-mud process? Why?

Answer. Because the bricks are generally too irregular in shape.

13. What principal action can be taken to avoid efflorescence on wall surfaces?

Answer. Make certain that good workmanship in terms of full mortar joints is carried out.

14. When mortar joints should be pointed?

Answer. Just before the mortar sets.

15. If header courses are ever used in laying up pilasters?

Answer. They are frequently used in pilasters, measuring 8″x8″x12″, etc.

16. When the backing tier is laid in an 8″ brick wall?

Answer. After the facing tiers have been completed between corners.

17. Why a bed of mortar should be placed on the top of a window frame before the steel lintels are placed?

Answer. To make the wall watertight and airtight between the lintels and the frame.

REVIEW QUESTIONS

1. When should brick be wetted before being laid?
2. Explain how to lay a closure brick in stringer course.
3. What is a queen closure and what is it generally used for?
4. What is the difference between a common and face brick?
5. Explain what stretcher and header courses are and the purpose of header courses in a wall.
6. What is the difference between soldier and rowlock courses?
7. What is the difference between head and cross joints?
8. What type joint finish is recommended for the joints in brick walls?

9. Why is it dangerous to use salt in mortar water during freezing weather?

10. What materials produce the red color in brick?

11. Would a *salmon* type brick be all right for use in a wall which supports heavy loads?

12. Why is bonding necessary in brick walls?

13. Give the important purposes of mortar.

14. Why should all joints between bricks in a wall be completely filled with mortar?

15. Is a thin mortar joint advisable in brickwork which must be strong?

16. Explain what means a bricklayer uses to be sure a course in the wall will be almost even with the tops of window frames.

17. Explain how a bricklayer makes sure that a course in a wall reaches exactly the right height for floor joists.

CHAPTER VIII

Masonry Sidewalks, Driveways, Floors, and Steps

QUESTIONS CHAPTER VIII WILL ANSWER FOR YOU

1. *What are expansion joints and where are they used in floors, sidewalks, and driveways?*
2. *What are the factors determining the widths, shapes, and thicknesses of masonry sidewalks and driveways?*
3. *What are the recommended proportions of cement, aggregate, and water for the average masonry sidewalk, driveway, floor and steps?*
4. *How is an even floor slope maintained in buildings which require floor drains?*
5. *What rule should be followed in designing treads and risers for concrete stairs?*

INTRODUCTION TO CHAPTER VIII

Masonry sidewalks, driveways, floors, and steps are such common, everyday items that the person using them seldom gives them a thought. It is only when these structures have been built too narrow or too steep or become badly cracked, broken, and uneven, in short, dangerous, that they come into prominence. Such a defect is immediately noticed and is an annoyance if not a genuine hazard. Even so simple an item as a concrete sidewalk requires careful thought, careful design, and careful building if it is to serve its purpose satisfactorily. The same is true for driveways. Floors and steps require even more care in their design and construction because of the added safety and cleanliness problems involved. For example, if, in stair construction, one riser (or height between steps) out of five or more is shorter or longer than the others, people using the stairs would tend to stumble in going up and down. It has been found that after two or three steps, people automatically learn the riser height and do not bother to actually look at the steps to see if there are any irregularities. It is evident then, that the construction of steps, sidewalks, driveways, and floors must be beyond reproach.

A careful study of this chapter will be a tremendous help in preparing you for the tasks involved in constructing these masonry items. You will learn first, the theory or purpose for each of the examples of masonry discussed in the chapter. The various representative kinds or types of masonry sidewalks, driveways, floors, and steps are described for you and their particular applications pointed out. Following this, you will discover a short section devoted to the design of these masonry items. Finally, you will read a detailed description of the actual building of these structures.

Once you have a thorough understanding of the material contained in this chapter, you will be adequately prepared to complete your study of

masonry sidewalks, driveways, floors, and steps through actual experience gained in the field.

THEORY OF SIDEWALKS, DRIVEWAYS, FLOORS, AND STEPS

The general theory behind the design and building of satisfactory masonry sidewalks, driveways, floors, and steps constitutes several points, all of which should be thoroughly understood before any of them are planned for any given situation. These items are not difficult and do not require any engineering knowledge nor much, if any, past

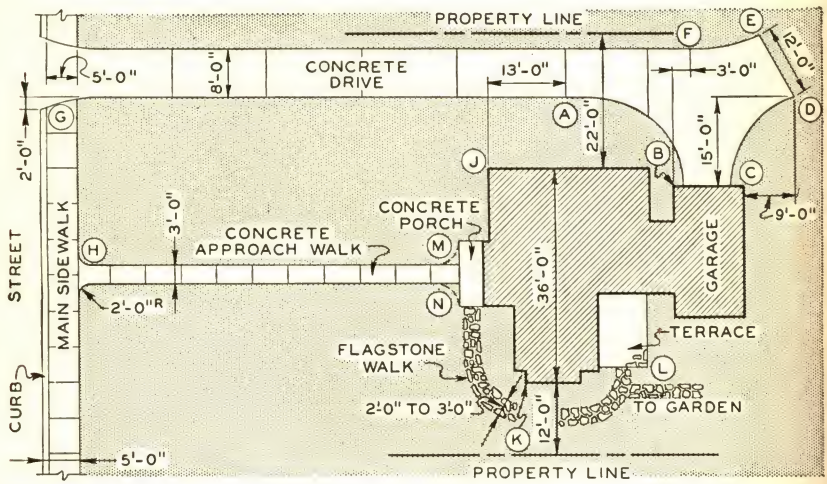


Fig. 1. Residence Sidewalk and Driveway

experience. If the subsequent explanations are carefully followed, no unsatisfactory results will be encountered in the simple design and construction procedures required.

Masonry Sidewalks. Sidewalks, first of all, should be made wide enough to accommodate the expected traffic on them and secondly, to have good proportions relative to the surroundings. In general, sidewalks are divided into two classes, namely, main and secondary walks. Main walks can be further divided into street and approach walks. In Fig. 1, the sidewalk along the street and the one leading up to the residence are main walks. The walk along the street is called a street walk and the walk leading to the residence is called an approach walk. The

flagstone walk which extends from one part of the residence to another part, or in other cases from the residence to a garden, etc., is a secondary walk.

Ordinarily, street walks are made at least 5′ 0″ wide in residential neighborhoods and up to 15′ 0″ or more in business sections of cities. A 5′ 0″ walk easily can accommodate residential district traffic and allow people to pass while walking in opposite directions. The wider walks for business districts allow for crowded conditions. Approach walks are generally made at least 3′ 0″ wide and secondary walks from 2′ 0″ to 3′ 0″ wide.

To be in good proportion to the surroundings, a walk, especially approach and secondary walks, must be wide enough to avoid the appearance of extreme narrowness. For example, if the approach walk in Fig. 1 were only 2′ 0″ wide, it would seem out of proportion to the rather large ground area and to the size of the residence.

For ordinary traffic and strength requirements, main and secondary walks should be at least 4″ thick and have a rather smooth surface. A concrete walk should have a base course of poured-in-place concrete at least 3″ thick and a top cement course approximately 1″ thick. Other masonry walks such as brick or flagstone also should have a base course approximately 3″ thick. There is one exception to this general rule which will be explained subsequently.

Great care must be exercised to see that walks are well aligned or square with intersecting walks and with residences or other buildings except where they are purposely made curving and twisting as are some secondary walks. If the approach walk in Fig. 1 were not square with the street walk and with the house, its effect would be annoying and would spoil the general appearance of the lawn. The irregularity of the secondary walk in Fig. 1 adds to the charm of the lawn.

Whenever a change of direction (a curve) is required in a sidewalk, care should be taken to make the curve long rather than short. A short curve, such as shown in (A) of Fig. 2, does not appear graceful, tends to crowd people when passing, and frequently causes them to break their stride. On the other hand, the curve at (B), being longer, has a much better general appearance and is much easier to negotiate. At points such as shown in (C) of Fig. 2 and at *H* in Fig. 1 where an approach walk meets a street walk, the approach walk can be slightly

curved or widened, to make a better appearing intersection. The radius of such a curve is usually from 2′ 0″ to 4′ 0″. In like manner if desired, curves can be made at *M* and *N* in Fig. 1 where the approach walk meets the concrete porch.

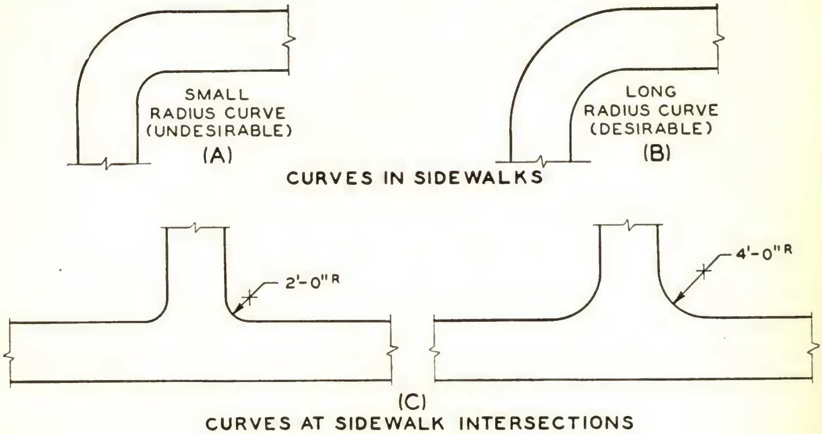


Fig. 2. Curves at Sidewalk Intersections

Many sidewalks of all kinds have cracked, broken, become uneven, generally annoying, and even dangerous because the soil under them was not properly prepared before the walks wre constructed. Almost any type of clay soil is either always wet or likely to be wet at various times. When wet, a clay soil loses much of its strength, leaving sidewalks or parts of sidewalks insufficiently supported with the result that the annoyances and dangers already set forth easily can take place. A clay soil will expand when frozen. Naturally, this expansion pushes upward on a sidewalk shoving it above the soil with the result that cracking and breaking are bound to take place. The thawing of the soil in turn causes the same results. To avoid such undesirable happenings, a thick layer of cinders or gravel should be placed as a foundation for all walks constructed in clay or wet soils. Cinders and gravel, even when thoroughly tamped, constitute porous materials through which water can drain easily or accummulate and freeze without harm to the sidewalk above. Cinders or gravel do not lose strength when wet and are sufficiently porous so that even if water does freeze in and around them they will not expand.

During warm weather, masonry sidewalks, especially those made all of concrete, will expand. This expansion really makes the walks stretch out or lengthen somewhat. Unless some means is provided in the sidewalk to absorb such lengthening, it will surely crack, bulge or break. If an expansion joint is built into walks at about 30′ intervals, any expansion which takes place will be sure to cause no damage.

Fig. 3 shows a typical expansion joint in a concrete sidewalk. Such a joint should extend the full width of the walk and include the full thickness of the base course. Note that the joint in the topping should be open approximately ⅛″ down to the expansion joint. Material for expansion joints generally can be purchased from lumber yards in various lengths and widths which can be cut to suit the needs of walks of any width and the commonly used 4″ and 6″ base course thicknesses. If this expansion joint material cannot be obtained, a soft pine board 1″ to 2″ in thickness can be substituted. It is best that such boards be treated with creosote to preserve them.

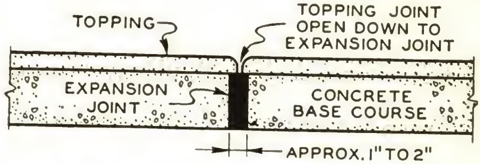


Fig. 3. Expansion Joint in Concrete Sidewalk

Any walk whose two ends intersect solid objects, such as other walks or buildings, should have at least one expansion joint, even if the walk is short. This practice allows for expansion and prevents any possibility of cracking or bulging.

Masonry sidewalks should never be placed on newly filled ground because as settlement takes place, perhaps unevenly, the soil compacts and thus does not properly support the walk. This always causes cracking, breaking, unevenness, and other annoying and dangerous results. Newly filled ground should be allowed to settle and compact for at least a year before building a sidewalk over it. In like manner, walks should never be laid on narrow mounds such as illustrated in (A) of Fig. 4, because the rain runs off the mound as shown by the arrows at *W* and *X*, causing within a short time, the condition shown by *Y* and *Z* in (B) of Fig. 4. Once this condition starts, the walk will soon crack, break, slide over to one side, etc.

The ordinary joints in sidewalks, such as shown in Fig. 1, extend only about ½″ into the topping course and generally are spaced not

more than 6′ 0″ apart. The spacing can be shorter in walks less than 4′ 0″ wide if desired. These joints add to the appearance of a walk and facilitate repairing it if the need arises.

In some instances, colored sidewalks are desired as a means of ornamentation for borders, etc. In any case, the coloring is used only in the top course and is very carefully and thoroughly mixed before and after water is added to the mix. The following recommendations for producing colored sidewalks are based on tests made by the Portland Cement Association and if carefully observed should result in satisfactory work.

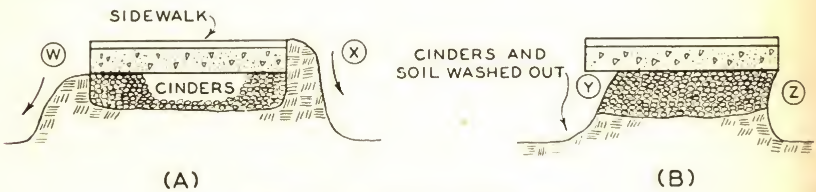


Fig. 4. Sidewalks on Narrow Fills

A pigment suitable for use in cement must fulfill the following requirements:

(1) It must be durable under exposure to sunlight and weather.
(2) It must produce intense color.
(3) It must be of such composition that it will not react chemically with the cement to the detriment of either cement or color.

These requirements are best fulfilled with mineral oxide pigments. Other pigments, such as organic dyes, have a tendency to fade and may even reduce the strength of the concrete. There are two kinds of mineral oxides available that are satisfactory—natural oxides that come direct from the mines and manufactured pigments which are prepared especially for cement work. Ordinarily, natural pigments cost less per pound and may be used where dull colors are satisfactory. However, where bright colors are desired, manufactured pigments produce best results. To achieve a given amount of color, more of the natural pigment is required than the manufactured pigment. It happens frequently that the smaller amount of manufactured pigment actually produces the desired results at a lower cost than the cheaper, natural pigment.

The following recommendations will serve as a guide in determining proper pigments for use in securing the colors listed:

Buff, yellow, or red	Iron oxide pigments
Green	Chromium oxide pigments
Blue	Cobalt blue
Brown	Iron oxide or iron and manganese oxide pigments
Slate gray and black	Iron oxide or manganese dioxide pigments

The color which is produced in cement work is determined primarily by the proportion of pigment to cement rather than by the proportion of pigment to the total volume of the mix. Because of this, modern color specifications give the weight of pigment to be used per sack of cement. It has been found that pigments may be used in amounts up to 10 per cent of the weight of cement—that is, 9 pounds of pigment per sack (94 pounds) of cement.

To obtain maximum clearness and brightness in colored finishes, white cement or a mixture of white and gray cement should be used. White finishes are obtained by using all white cement.

Generally, sidewalks should have a smooth finish. However, a rough finish is desirable sometimes to overcome the tendency toward its being slippery. How to obtain various finishes is explained in succeeding pages.

Sidewalks should have their surfaces slightly sloped so that water will run off readily during rains and thawing snow or ice. The slope should be almost unnoticeable to the eye and certainly not enough to constitute a walking annoyance. It is best that the slope be from one side of the walk to the other.

Masonry Driveways. A driveway should be wide enough to accommodate an automobile or truck without too much care being required by the driver to keep the wheels on the driveway. This is important because during wet weather or at times when snow and ice are present, even one wheel off the driveway could easily cause trouble in addition to cutting ruts in a lawn. Because of this, the paved type driveways are made from 8′ to 10′ wide. It will be noted that the approach part of the driveway in Fig. 1 is 8′ 0″ wide. If curbs are desirable, they should be beyond a minimum 8′ 0″ width.

The widths of driveways should be materially increased on curves or places where facilities are provided for turning completely around.

For example, the area *ABCDEF* in Fig. 1 allows enough room for backing a car out of the garage, then turning it to head for the street or of turning so as to back it into the garage.

A good concrete driveway should be at least 6″ thick because of the weight of cars and because at widths of 8′ or 10′ such a thickness is required for over-all strength. The strength can be increased further by using heavy wire mesh in the concrete as reinforcing.

As explained for sidewalks, driveways must be carefully aligned or squared with relation to the street or the shape of the building site. The driveway in Fig. 1 would be an eyesore if it did not intersect the street at right angles and was not parallel to the approach sidewalk. Sometimes designers curve such a driveway as a means of relieving the monotony of the severe straightness. This would be all right except that it sometimes makes steering more difficult for the driver. If building sites are situated at an angle to the street, then driveways also may be at an angle.

As explained for sidewalks, the soil under a driveway must be treated with a layer of cinders or gravel in order to prevent cracking, breaking, etc. This is especially true for driveways because of the heavy automobile loads they must support.

Expansion joints in driveways are necessary at not more than 3′ 0″ intervals for the same reason as explained for sidewalks and are made in exactly the same manner.

It is dangerous to lay a concrete drive on newly filled ground because of the settling and compacting of the soil which gradually takes place. The driveway might not only crack or break but might suddenly slide or break off in large sections just at a time when a car was passing over it. For all newly filled ground, it is best to allow at least a year's time for settling and compacting before laying a driveway.

Concrete driveways, like sidewalks, should have their top course or surface divided by ½″ deep joints spaced not more than 15′ 0″ apart. Such joints can be spaced at more frequent intervals: for example, every 6′ 0″ if desired.

The surfaces of concrete driveways may be smoothed like a sidewalk or they may be finished more roughly, somewhat similar to a concrete highway. Generally, the smooth surface looks better when used in connection with residences.

Color can be used for decorating concrete driveways following exactly the same explanations given for sidewalks.

The slope necessary for concrete driveways can be made in one or two ways, as shown in Fig. 5. For driveways on practically level ground like the one illustrated in Fig. 1, the slope should be from a center line crown as shown in (A) of Fig. 5. If a driveway is situated on ground that has a general slope at right angles to it, then the depressed center line shown in (B) of Fig. 5 is best because the water can run off easily. The amount of slope or pitch need not be more than the 2″ as indicated in Fig. 5.

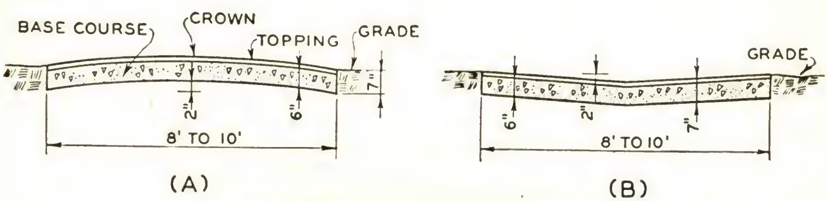


Fig. 5. Slope for Concrete Driveways

Curbs may be used with driveways if their added cost is not serious so far as the allotted budget is concerned. Curbs give a driveway added beauty, dressing it pleasingly.

Masonry Floors. Most concrete floors for basements, garages, dairy barns, granaries, cattle barns, etc., should be from 4″ to 6″ thick. In cases where no exceptionally heavy traffic is expected, the 4″ thickness is ample. Where machinery or heavy use is expected, the 6″ thickness should be used. The thickness of a floor should be uniform over its entire surface. For floors having a 6″ thickness, added strength can be provided by putting a heavy wire mesh in the concrete.

Unless floors are poured in sandy soil, it is best to excavate 6″ to 8″ deeper and fill the added depth with cinders or gravel. This will prevent any possible cracking or buckling because of moisture or freezing. Such practice also helps to waterproof the floor.

Floors in basements and garages or barns should have a decided slope or pitch so that laundry water, auto washing water, etc., will run quickly into the drains provided. The slope should be at least ¼″ to every foot. Fig. 6 shows plan and section views of a typical concrete floor for a two-car garage. Note that all floor areas such as *ABC, ACD,*

DCE, and *ECB* all slope toward the drain. Floors used for first floors in residences, in granaries, etc., where no water is involved can be perfectly level throughout.

Floors are not generally exposed to the sun and in most cases are in cool places where appreciable changes in temperature are likely. Thus a great deal of expansion need not be expected. However, it would be wise to make some provision for possible expansion. It is recommended that an expansion joint be constructed all around the edges of floors where they meet side walls or foundations. For example, in Fig. 6 it would be wise to make a continuous expansion joint where the floor meets the walls along sides *BA*, *AF*, and *FG*. The cost is not great and the benefit is insurance against the appearance of cracks.

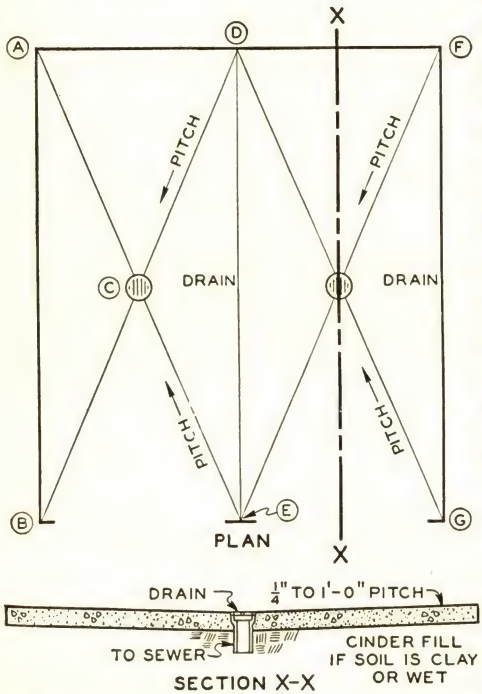


Fig 6. Details of Pitch to Facilitate Draining of Concrete Garage and Basement Floors

If trenches for sewers and drains are dug, for example, in a residence basement, they should be carefully backfilled and tamped to avoid future settlement. Such settlement under a floor is apt to cause not only cracks but actual breakage as well.

The surfaces of floors should be finished smooth for easy cleaning and ready drainage of water. If carpeting or linoleum is to be laid directly on a concrete floor, the surface should be made somewhat rougher in order to increase the adhesion of the cement between the padding and the concrete floor.

Joints are unnecessary in floors and are not usually made because they constitute a dirt-collecting source which is difficult to clean.

Color may be used in recreation room floors to great advantage. The instructions given for color in connection with sidewalks applies equally well for floors.

Masonry Steps. One of the most important features of masonry steps is the *treads* (the part stepped on) and *risers* (distance between treads). These must be planned to provide comfortable use and safety. The risers should bear a certain relation to the width of the treads and at the same time should be between 6″ and 8″ in height. Low risers and broad treads are generally preferred, especially for exterior steps. High risers and narrow treads should be used only where the horizontal distance into which the stairs must fit is limited. A desirable formula to use for steps is twice the height of the riser plus the width of the tread equals 25. It is a good plan to have the treads project about ½″ beyond the face of the riser.

The width of stairs depends to some extent upon the sidewalks used in connection with them and upon the expected traffic. In general, steps should be at least 3′ 0″ wide or wider, depending on what must be taken up and down them. Wide steps seem to cause less mental hazard for the people who use them.

Curbs on either side of steps provide an added means of dressing the stairs and making them more pleasing in appearance. However, there is no other advantage worth contemplating in terms of cost.

Steps should never depend on newly filled ground for support because where steps are placed over such soil, cracking and even breaking are almost sure to occur. If for some reason it is absolutely necessary to place steps over such soil, they should be designed so as to be self-supporting.

The treads of exterior steps should be sloped away from the risers so that the pitch is about $\frac{1}{16}$ inch. This practice makes certain that water and ice do not accumulate to become a danger.

If steps are to be supported by the soil, the area under them should have a thick layer of cinders or gravel as for sidewalks.

The surface of treads can be smoothed as explained for sidewalks or they can be made rough depending on their location and intended use. If they are used in connection with some activity where they might become slippery, it is best that they be finished rough, using a wood float or trowel rather than a steel trowel.

Steps having brick or flagstone surfaces have concrete bases built like ordinary concrete steps. The bricks or stones are then laid up in mortar and have their joints filled with mortar.

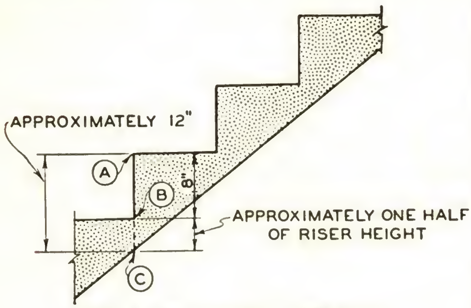


Fig. 7. Concrete Step Thickness

Any concrete steps, if not firmly supported by the soil, should be strengthened by the use of steel reinforcing bars extending throughout their length. Such steps also require footings.

As indicated in Fig. 7 the total thickness, that is *AB* plus *BC*, should be such that *BC* is approximately one-half of the riser height. A dimension for *BC* less than that specified will result in steps which are structurally inferior.

Color may be incorporated in the steps, as explained for sidewalks.

KINDS OF MASONRY SIDEWALKS, DRIVEWAYS, FLOORS, AND STEPS

Obviously, all varieties of such masonry items could not be discussed in this chapter. However, representative or typical kinds are shown and illustrated.

Masonry Sidewalks. Street, approach, and secondary sidewalks were explained previously in connection with Fig. 1. However, some added explanations are given here.

CONCRETE SIDEWALKS. Fig. 8 shows the details of a concrete sidewalk in general. These details apply to street, approach, and secondary sidewalks alike. Note that the joints should be uniformly spaced and that center joints should be employed whenever sidewalks are over 15′ 0″ wide. In the section view, note the top and base courses and the cinder or gravel fill.

FLAGSTONE WALKS. Flagstone walks, as shown in Figs. 9 and 1, frequently are used for secondary walks especially in lawn and garden areas. Generally they are laid so they are continually curving as a means of adding more beauty to the lawn or garden. The stones employed may be of practically any shape except that their edges must be trimmed so that the two sides of the walk are fairly uniform. The usual

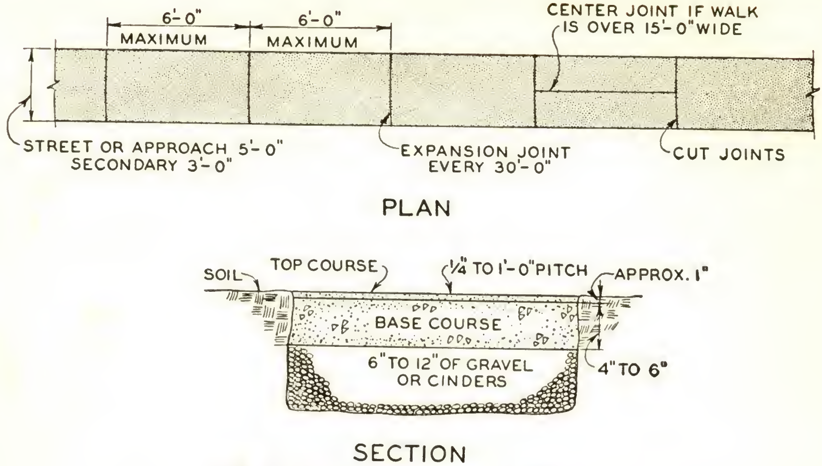
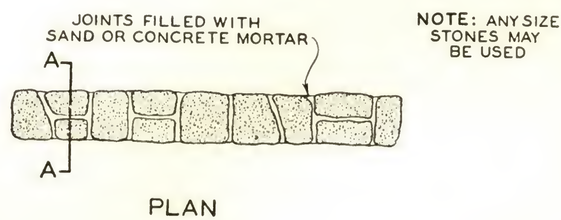


Fig. 8. Details for Concrete Sidewalk

thickness for the stones is approximately two inches. Such sidewalks also can be used for approach walks of any required width. However, they look best at widths of 3′ 0″ or less. The stones can be laid either in sand or on a concrete base. The concrete base with mortar joints is



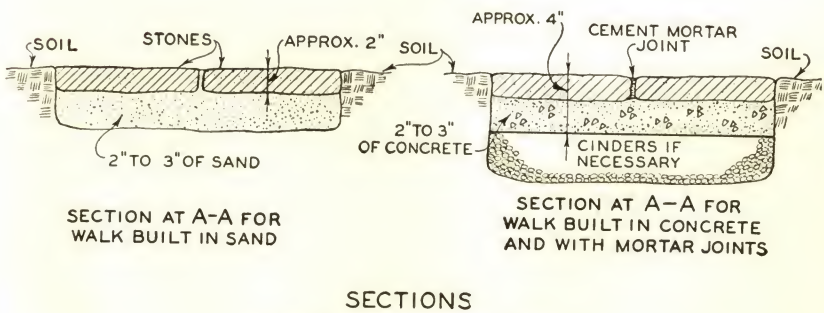


Fig. 9. Details for Flagstone Walk

recommended due to its ability to stand hard use and still keep its required shape and level. Cinder or gravel fills also are recommended in clay or wet soils.

Brick Sidewalks. Brick sidewalks, like those of flagstone, make pleasing secondary walks, especially in garden areas. Fig. 10 shows section views of a brick walk having sand and concrete bases. In both sections, the sand settling bed is employed as a means of providing a softer walk. The principle involved is that the sand gives a little as a person walks, thus providing more comfortable walking. However, there is the disadvantage that the bricks are easily displaced and frequently become uneven. For this reason, the brick walk having a

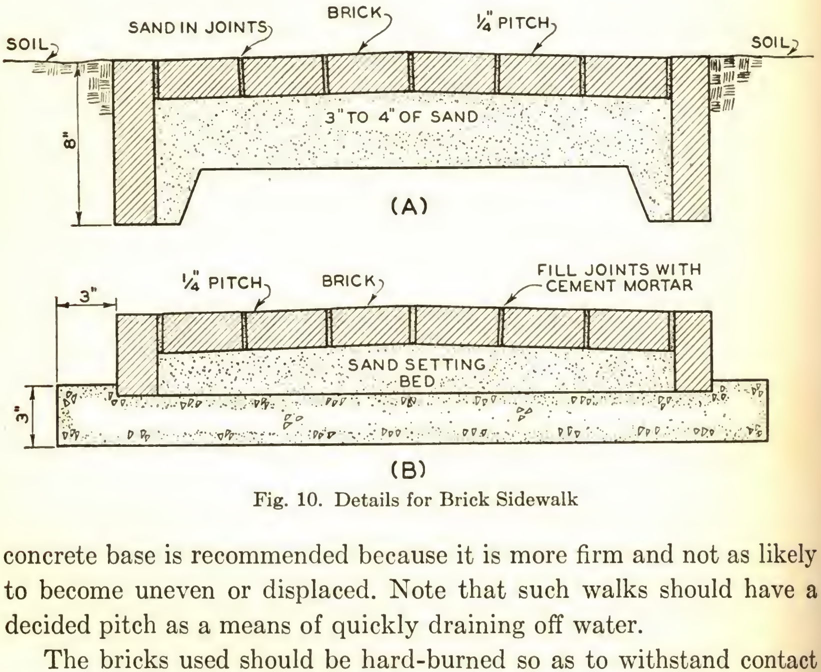


Fig. 10. Details for Brick Sidewalk

concrete base is recommended because it is more firm and not as likely to become uneven or displaced. Note that such walks should have a decided pitch as a means of quickly draining off water.

The bricks used should be hard-burned so as to withstand contact with the soil. Various color combinations and patterns can be worked out, many of which are indeed pleasing in lawn and garden areas.

A more practical brick walk can be made using a concrete base 3″ thick, placing the brick directly on the concrete while it is still wet and plastic. If the joints are filled with mortar, such a walk is quite durable.

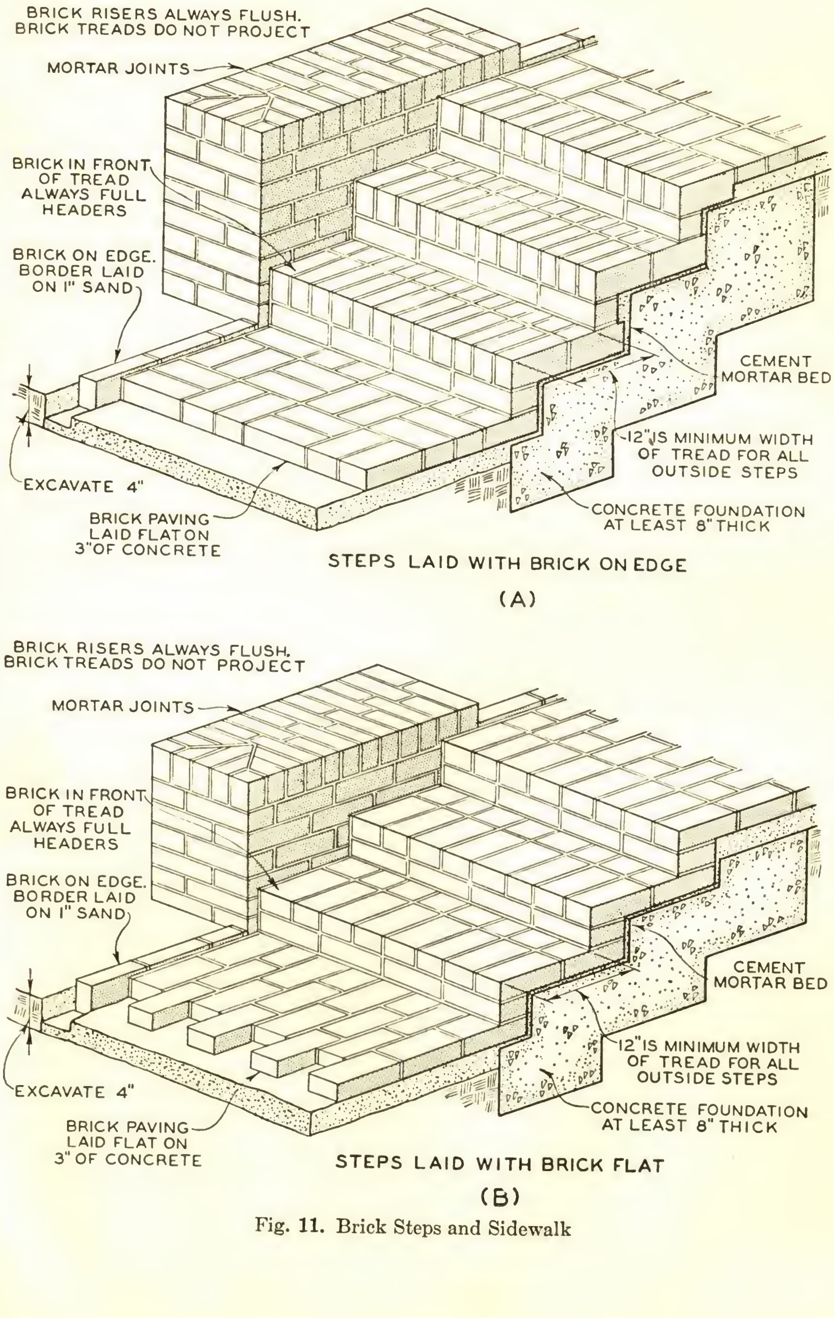


Fig. 11. Brick Steps and Sidewalk

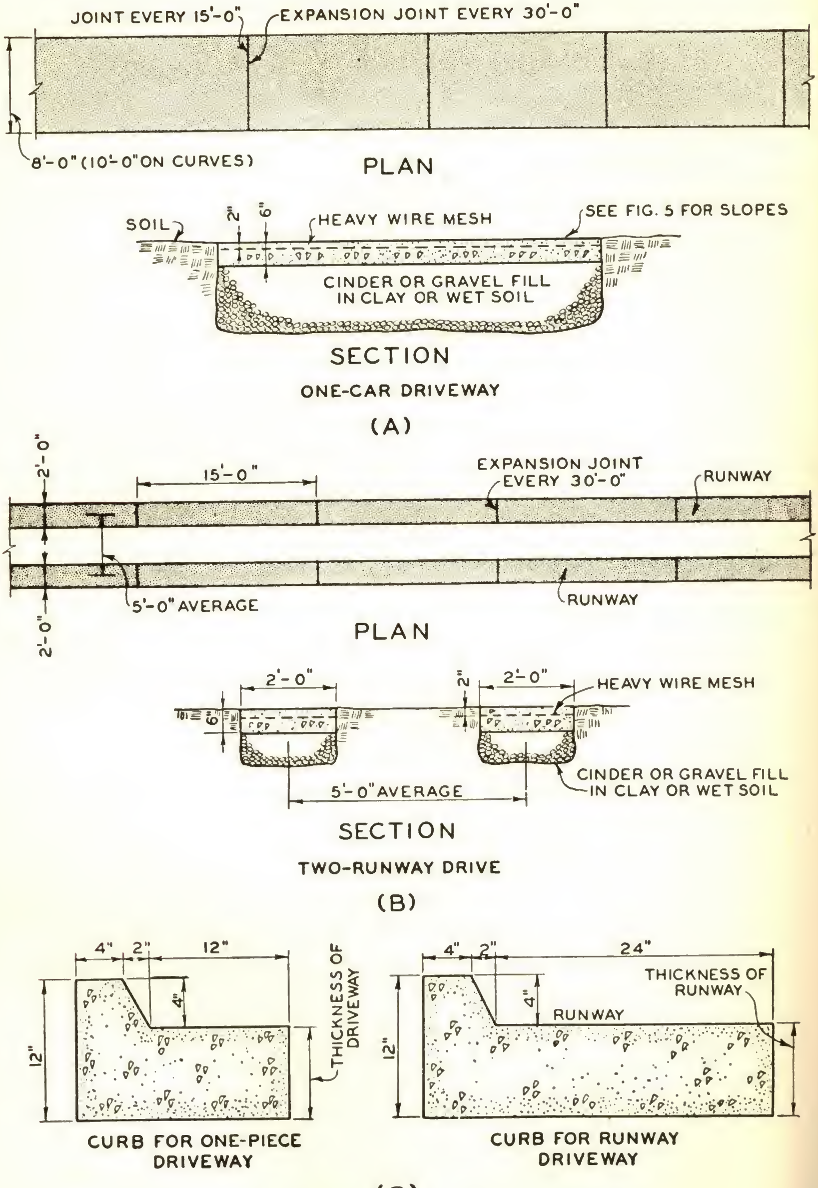


Fig. 12. Details for One-Car Driveways

Fig. 11 further illustrates and explains the type of brick walk explained in the previous paragraph.

Masonry Driveways. Driveways are built of the same materials used in the construction of masonry walks. Of these, concrete is the most widely used.

CONCRETE DRIVEWAYS. Concrete driveways frequently are made all in one piece and in two separate runways, as illustrated in (A) and (B) of Fig. 12. The one-piece type, also shown in Fig. 1, is perhaps the more

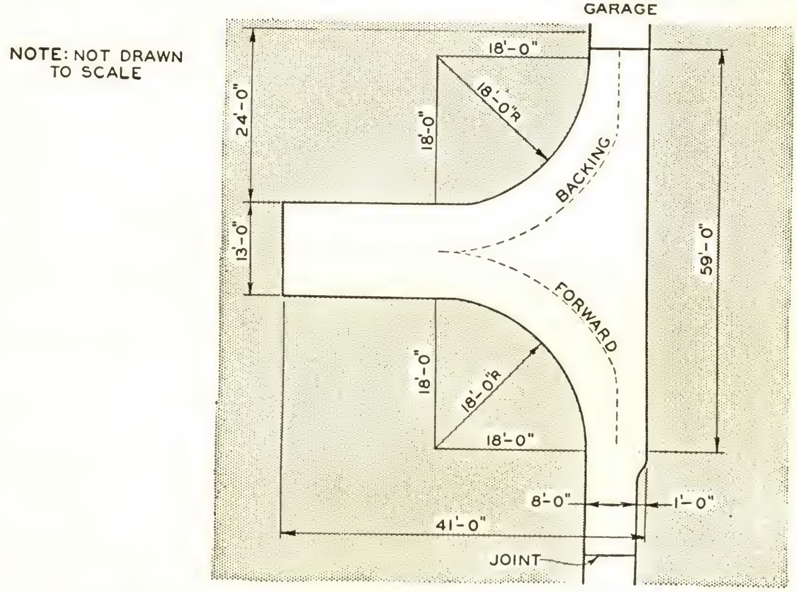


Fig. 13. **Y** Turn in Driveway to Provide Means for Backing into Garage

practical, although its cost in materials exceeds the two-runway type. Both kinds may have curbs added, as shown in (C) of Fig. 12.

Note in (B) of Fig. 12 that the two runways are 2′ 0″ wide and that their distance apart is, on the average, 5′ 0″. All dimensions can be changed to fit existing conditions. Note in both (A) and (B) of Fig. 12 that heavy wire mesh is recommended as a means of adding strength to the concrete. Such reinforcing tends to avoid temperature stress cracks as well.

Fig. 13 shows a **Y** turn which is somewhat more pronounced than the one illustrated in Fig. 1. This turn allows considerably more free-

dom in turning a car but also costs more than the one shown in Fig. 1. Both kinds are recommended.

Flagstone and Brick Driveways. Driveways also may be built of flagstone or brick set directly on the concrete, with joints filled with strong mortar. Such driveways resemble the flagstone and brick sidewalks in construction. Either the one-piece or runway-type makes a pleasing driveway especially in lawn or garden areaways. Neither is recommended for heavy duty.

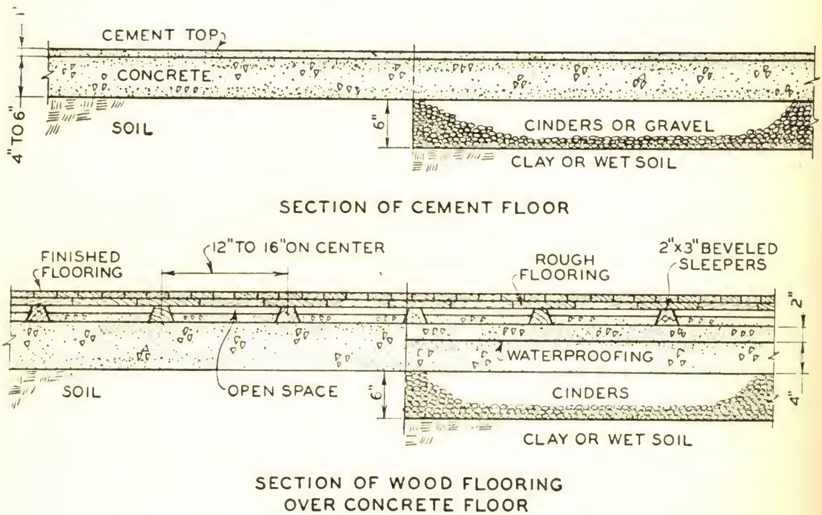


Fig. 14. Details of Cement, and Concrete and Wood Floors

Masonry Floors. Fig. 14 shows two common kinds of concrete floors. The plain concrete floor is generally employed for basements, porches, garages, granaries, haymows, etc. When wood flooring is required over a concrete sub floor, some arrangement must be provided for nailing or securing the rough wood flooring. This is generally accomplished by placing 2″ x 3″ beveled wood sleepers spaced 12″ to 16″ on centers on the concrete, then filling in between them with concrete except for a small air space between the concrete and the underside of the rough wood flooring. Sometimes such floors are waterproofed as a further means of preventing dampness beyond the cinder or gravel fill, by pouring the concrete in two layers, putting waterproofing of tar and felt, or asphalt and felt between the layers.

Flagstone and Brick Floors. In many instances, terrace floors, such as in Fig. 1, are made with concrete bases and flagstone surfaces. Sometimes brick surfaces are used over a concrete base. In either case, the concrete base is recommended with the stones or bricks laid directly on the concrete. The joints should be filled with strong mortar.

Occasionally porches, especially rear door porches for residences, have a combination concrete floor and steps. Such a combination is explained in succeeding pages.

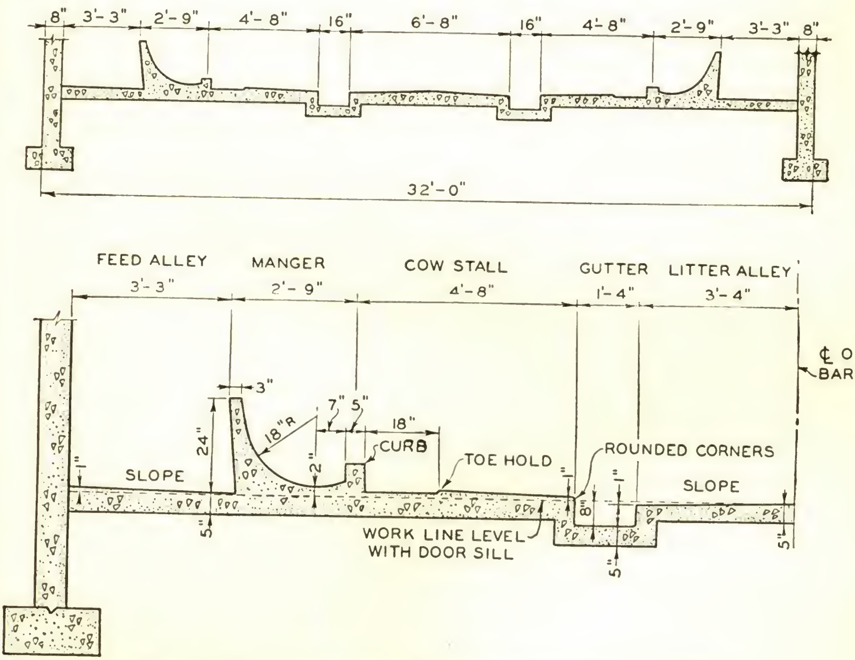


Fig. 15. Dimensions for a 32′ 0″ Dairy Barn Floor and Details

Concrete floors are widely accepted as the most practical, economical, and sanitary floors in dairy barns. The impervious surfaces of such floors do not absorb odors and can be readily cleaned and disinfected. Fig. 15 shows the usual dimensions for a dairy barn floor for a barn 32′ wide and gives the details and dimensions for the standard cow stall.

Masonry Steps. Perhaps one of the most common kinds of concrete steps are those used as a means of entering a basement from the

outside. Such steps are shown in Fig. 16. These steps are supported by the soil. Note the footing at *A* for spreading the weight over a large area. Note also that the top step and the sidewalk are in one piece. This construction tends to overcome the possibilities of cracks and other annoyances.

In (A) and (B) of Fig. 17 are shown two kinds of steps commonly used where a terrace is encountered in connection with sidewalks. The steps at (A) have curbs while those at (B) are plain. Note that at (A) the steps have a footing and that the sidewalk is not an integral part of the steps, while at (B) the lower portion of the stairs are thickened and are an integral part of the sidewalk. Both steps are supported by the soil.

The steps shown in Fig. 18 are self-supporting, reinforced with steel rods, and have a foundation which is not integral with the sidewalk. Such steps are commonly used where a concrete front porch for a residence is several feet above grade. Note how the top of the steps is notched into the porch foundation wall.

Another commonly encountered type of concrete stair is shown in Fig. 19. Here the small porch and the steps are all one piece of poured concrete.

The brick and concrete steps shown in Fig. 11 are frequently used in connection with ornamental brick porches or outside terraces. They are pleasing but expensive to build, especially with regard to labor costs.

DESIGN OF MASONRY SIDEWALKS, DRIVEWAYS, FLOORS, AND STEPS

To a great extent, the design of these masonry items either has been explained in previous material or clearly shown in the various illustrations. Therefore, the following information contains only such additional explanations as are considered necessary for typical items. Fig. 20 shows a typical plan view of a lot including the residence location and garage, the sidewalks, driveway, and typical floors. This is the type of drawing which should be made in order to plan all such items to the best advantage prior to the start of actual work.

Sidewalks. In Fig. 25, the street walk is shown as 5′ 0″ wide. This is the dimension most generally employed for such walks. In any event,

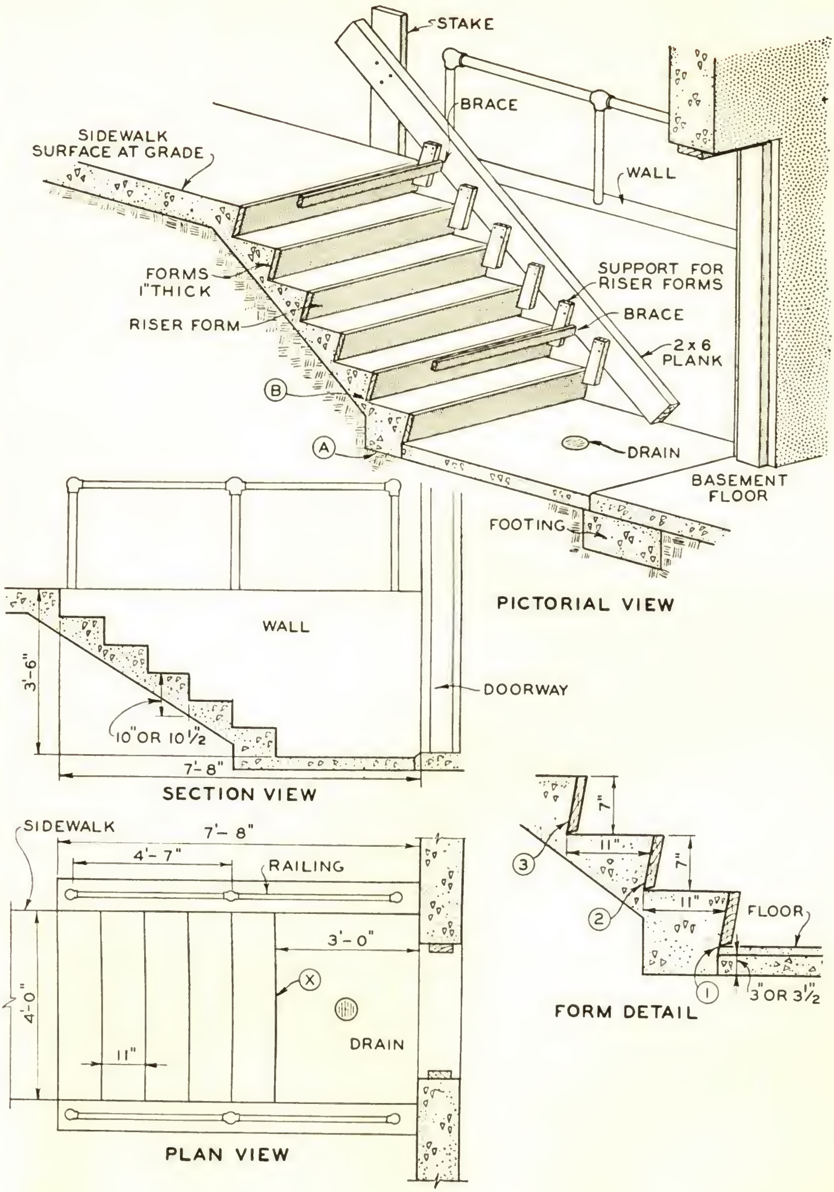
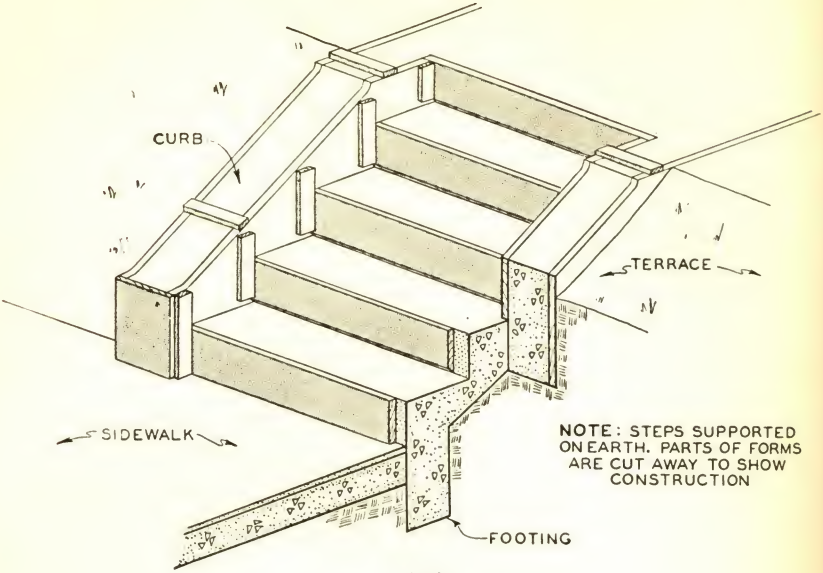
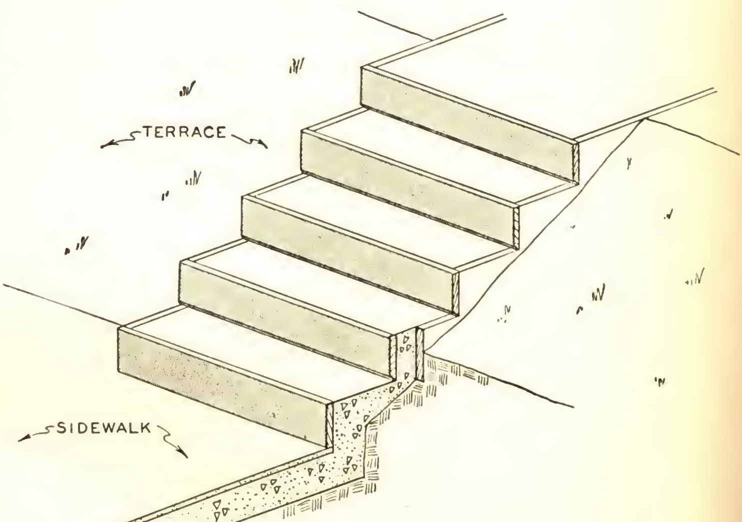


Fig. 16. Basement Steps



(A)



(B)

Fig. 17. Steps for Sidewalk Change of Elevation Due to Terrace

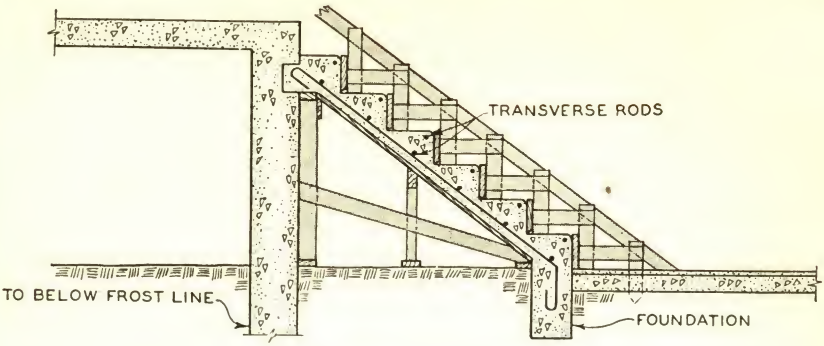


Fig. 18. Self-Supporting Steps

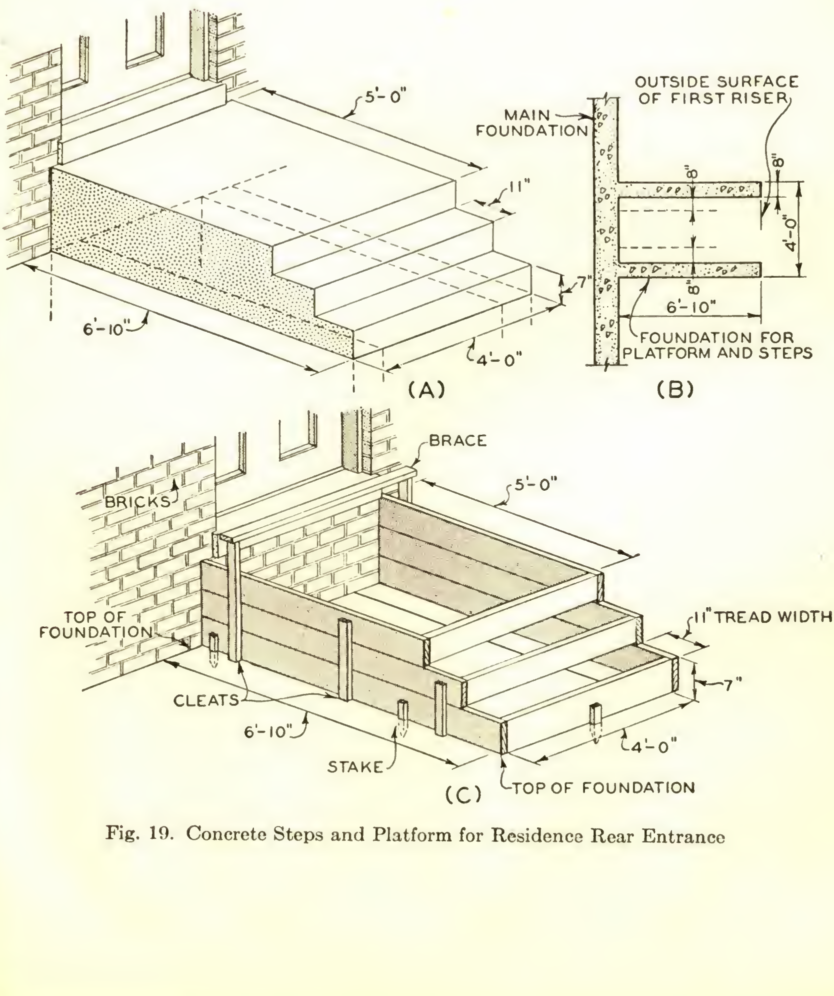


Fig. 19. Concrete Steps and Platform for Residence Rear Entrance

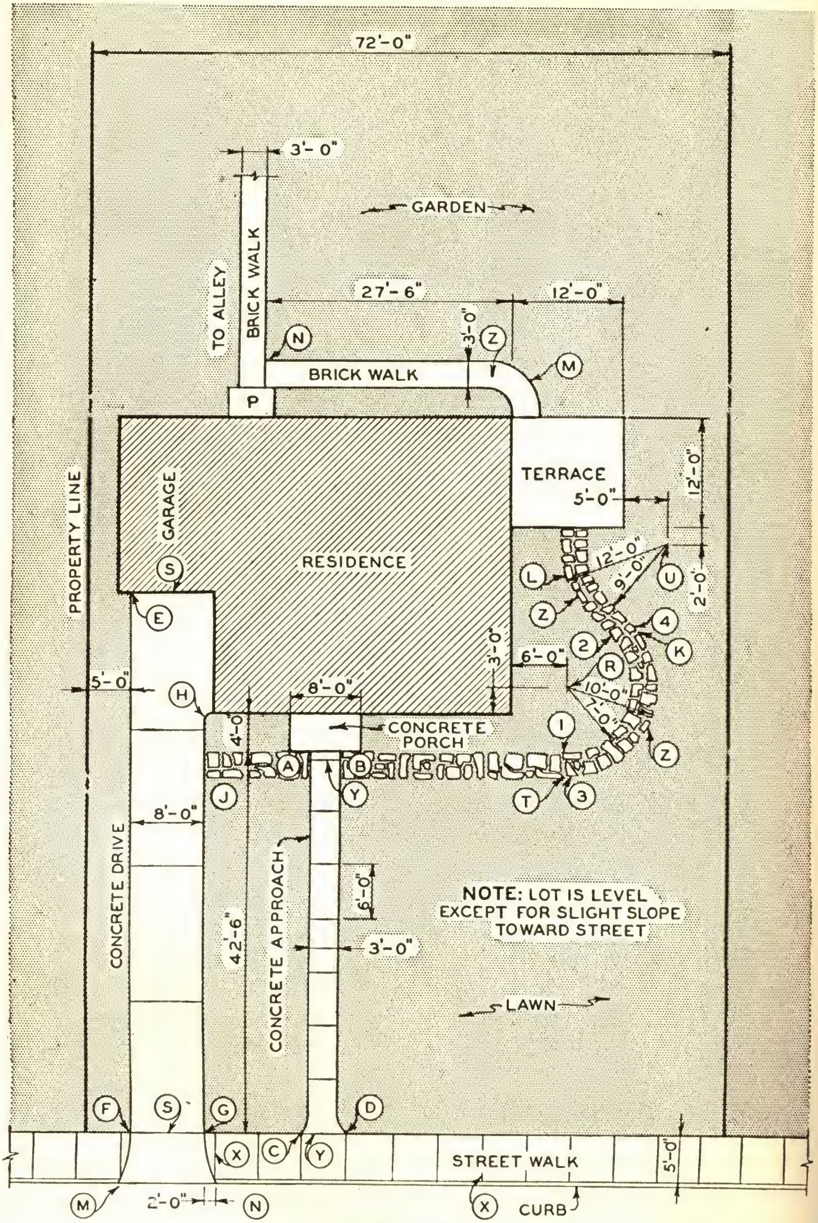


Fig. 20. Layout of Sidewalks and Driveway

this walk must be made the same width as any existing street walk on near-by lots or as specified by city building codes. The approach walk is 3′ 0″ wide with joints every 6 feet.

Both the street and approach walks are to be made of concrete so expansion joints must be considered. The street walk is roughly 72′ 0″ long so at least two expansion joints will be required as indicated at *X*. The approach walk is roughly 42′ 6″ long. It is best to have expansion joints at the points marked *Y*. Both of these concrete walks should be placed on cinder fills and be at least 4″ thick, including a topping of approximately one inch.

From the front entrance porch to the terrace, a flagstone walk extends to the driveway and to the terrace. These walks are 3′ 0″ wide, should have a 3″ concrete base, 2″ thick stones, and joints filled with strong cement mortar. Note that the walk leading to the terrace curves according to the radii shown. A cinder fill also is necessary.

From the rear entrance porch, one brick walk leads to the terrace and one to the alley. Both are 3′ 0″ in width and should be laid directly on a 3″ concrete base with all joints filled with strong cement mortar. A cinder fill is necessary.

Both the curving flagstone walk and the two brick walls should have expansion joints at the points marked *Z*.

Driveways. The driveway shown in Fig. 20 is a simple, straight design. A Y is not used because of the lack of room. This driveway is to be made of concrete which is 6″ thick, including a topping of approximately one inch. Its width is to be 8′ 0″ except at point *H* where it widens slightly. Two expansion joints are recommended as shown by the letter *S*. A cinder fill is required.

Floors. In Fig. 20 it can be assumed that the 4′ 0″ x 8′ 0″ front entrance porch is 4″ above grade. This porch must have footings (or a foundation) under it as shown in Fig. 21. These footings should be 6″ thick and should extend below the frost line. They should be poured at the same time as the foundation for the residence and should be an integral part of it. The 4″ concrete porch floor is poured directly over these footings and is supported by them and by the unexcavated soil. The rear entrance porch is of the same general design.

The terrace floor is to be flagstone set directly on 4″ of concrete and with joints filled with strong mortar. The surface of the terrace

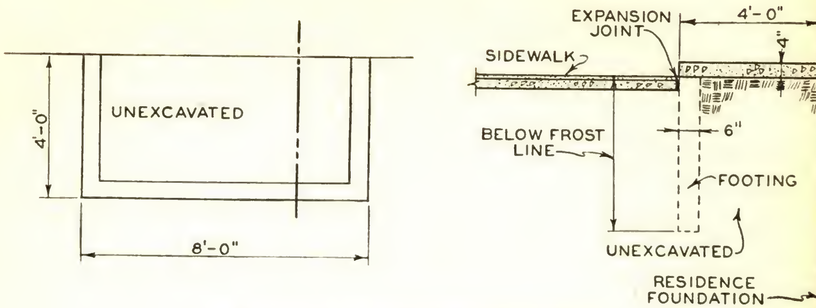


Fig. 21. Details of Front Entrance Porch

should be practically level with the surrounding lawn. A cinder fill is necessary.

The garage floor (see Fig. 22) is to have one drain and the floor is to slope, at the rate of ¼″ for each lineal foot in the four directions shown by *A*, *B*, *C*, and *D*. The concrete should be 4″ thick including approximately a 1″ topping and is to be poured over a cinder fill.

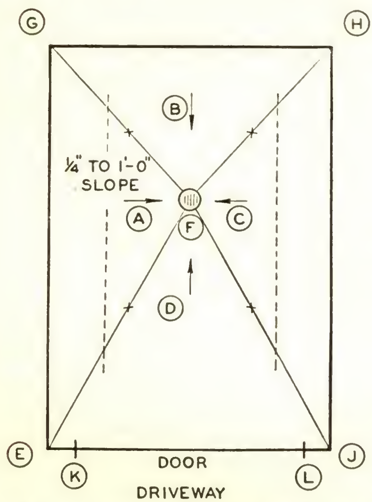


Fig. 22. Details of Garage Floor and Drain for Residence Shown in Fig. 20

The basement floor for the residence indicated in Fig. 20 can be of the same general design explained for the garage floor except that expansion joints should be provided all the way around where the floor meets the foundation.

The design of the barn floor shown in Fig. 15 is self-explanatory from the data given in the illustrations.

Steps. Suppose a residence basement floor was 3′ 6″ below grade line and that concrete steps were required for an exterior entrance to the basement. The stair design shown in Fig. 16 is designed for such a case. Each of the risers can be 7 inches. Thus, 6 risers would be required for a difference in level of 3′ 6 inches. The treads, by the rule, should be 11 inches. The thickness of the stairs, following the rule

explained for Fig. 7, can be approximately 10″ or 10½ inches. A cinder fill is required to a depth of approximately 6 inches. Other steps, such as those shown in Figs. 17 and 19, can be designed in like manner. Curbs vary in width but for steps from 3′ to 6′ wide, a curb thickness of from 6″ to 12″ is good proportion.

For self-supporting, reinforced concrete steps, the general design procedure is the same as that just described except that steel reinforcing rods are necessary as shown in Fig. 18. A structural engineer should be consulted for information as to the number and spacing of such reinforcing rods.

BUILDING MASONRY SIDEWALKS, DRIVEWAYS, FLOORS, AND STEPS

The following building explanations are given for typical sidewalks, driveways, floors, and steps, with the assumption that if such typical items are explained, the same principles plus the almost self-explanatory sketches given throughout this chapter can be used for any specific project the reader may have in mind.

Sidewalks. Probably the most often constructed item the average mason is called upon to build is the sidewalk. By far the most common walk is one built of concrete.

CONCRETE SIDEWALKS. Suppose it is desired to build the approach sidewalk shown in Fig. 20. The entire lawn is level except for a slight slope toward the street. This slope automatically takes care of draining water from the completed walk. Since the lawn is practically level and at the correct grade, an excavation must be made before the cinder fill and concrete can be placed. This will allow the concrete of the finished sidewalk to be at the same level as the lawn.

Starting at the residence, the walk should be centered on the porch. First, drive two stakes at *W* and *X* as shown in (A) of Fig. 23, so that the inside edges of the stakes are exactly 3′ 0″ apart. Then drive two more stakes at *Y* and *Z* in the same manner. The proper alignment for the stakes can be secured by measuring from the property line to stakes *W* and *X*.

Next, stretch heavy cord from stake *W* to *Y* and from stake *X* to *Z*. These cords should be from 3″ to 4″ above the soil and pulled tight. Then excavate two parallel trenches, see (B) in Fig. 23, under the full

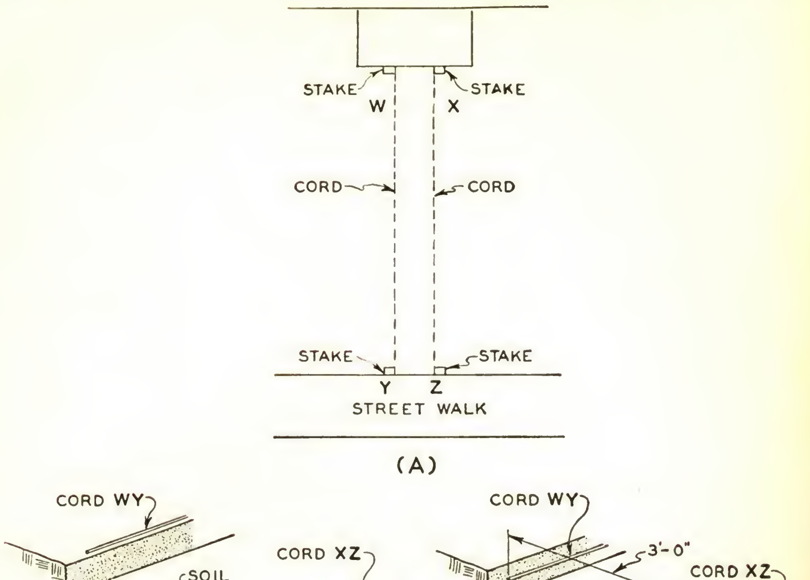


Fig. 23. Building Details for Concrete Approach Walk in Fig. 20

length of each cord about 6″ wide and 5″ deep. These trenches are to allow the wooden forms to be placed. After the trenches are excavated, lower the cords to the level of the lawn (this becomes a guide for the level of the walk) as shown in (C) of Fig. 23.

Forms most generally can be made using 2 x 4 lumber. Select straight

pieces for good results. These 2 x 4 forms must be held in place by 2 x 4 stakes spaced so that the forms can be nailed to them. Lay the 2 x 4 pieces along both sides of the trenches to estimate roughly where they must be joined and in order to provide a stake at those points.

Now drive 2 x 4 stakes approximately 6′ 0″ apart along both trenches so that they are 2″ outside of the cords *WY* and *XZ*, as shown in (D) of Fig. 23, and with their tops no higher than the cords. Nail the 2x4 forms to the stakes as shown in (E) of Fig. 23. The forms are now complete except for the curves near the street walk and for leveling up just before concrete is poured. The cords can now be removed along with their stakes *W*, *X*, *Y*, and *Z*.

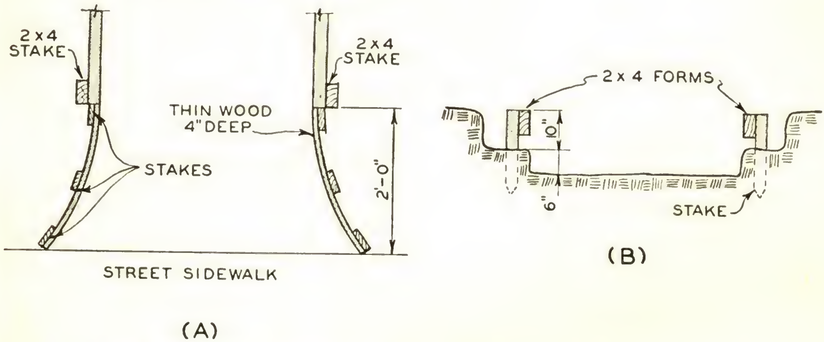


Fig. 24. Building Details for Concrete Approach Walk in Fig. 20

If the 2 x 4 forms are left about 2′ 0″ from the main walk, as shown in (A) of Fig. 24, then thin wood, 4″ deep, can be bent and held in place by stakes as shown.

The next step is to complete the excavation, as shown in (B) of Fig. 24. If the cinder fill is to be 6″ deep, then the excavation must be made 10″ deep to make room for both the cinders and 4″ of concrete. The correct depth of excavation can be judged by placing a board across the forms and measuring down from this board at frequent intervals.

Dump the cinders into the excavation by wheelbarrow or shovel, taking care not to disturb the forms. Tamp the cinders into a firm mass, using a wooden or steel tamp. The cinders should not be above the lower edges of the forms. Be sure that the surface of the cinder fill is practically level.

Next, the forms should be checked using a mason's level to see that they are level. This is done by placing the level on and parallel to the forms at frequent intervals and by putting the level on a 2 x 4 plank stretched across the forms at right angles to them at frequent intervals. The forms can be lowered by driving one or more stakes down a little. If the forms are too low, they can be separated from the stakes and renailed at the proper place. Also check the width of the forms to make sure they are exactly 3′ 0″ apart all along the length of the walk. Go to one end of the forms and sight along each one to make sure they form a straight line. If any crookedness is noted, separate the forms from the stakes at the required places, redrive the stake, renail, and recheck using the level. Place the expansion joint material up against the street sidewalk and the porch at the points indicated as *Y* in Fig. 20.

The concrete for the base of the sidewalk can be made using a 1:2¼:3 mix for dense concrete or 1:2:4 mix for ordinary projects. The topping can be either a 1:2 or a 1:3 mix of cement and sand. The base concrete should be rather stiff so that it requires tamping, while the topping mortar should be wet enough to spread easily.

Place the concrete to approximately the full depth of the base along a stretch of several feet. Then, using a base gauge shown in Fig. 25, level off the concrete carefully. Tamp it firmly using a regular tamper. The base concrete should not be lower than ¾″ to 1″ below the tops of the forms.

The topping should be placed very soon after the base has been tamped. Dump the topping on the concrete to approximate thickness and then level, using a straightedge also shown in Fig. 25. The straightedge should be used with a sawlike motion as it is gradually advanced along the tops of the forms.

Allow the topping to harden until it becomes quite stiff, then finish it with a wood float as smoothly as possible. See (A) of Fig. 26. Then round the edges along the forms and make the joints or grooves as shown in (C) of Fig. 26. Finally use the steel trowel, as shown in (B) of Fig. 26, to make a smooth dense surface. This finishing trowel should be used sparingly, since excessive troweling produces surfaces which, after hardening, tend to check and dust.

If practical, all of the pouring for concrete sidewalks should be

done in one day. If this is not possible, a stop form, shown in Fig. 25, can be placed at the end of the day's work. Top course should always be placed over the base course the same day and never delayed overnight.

In summer the forms can be removed safely after two days and the walk used after four days. During cold weather, never remove forms in less than a week's time and do not use the walk for at least ten days.

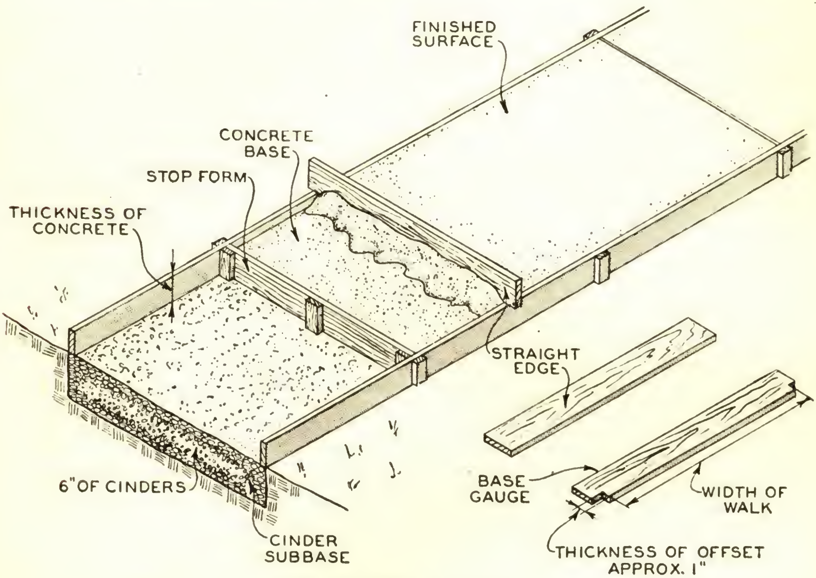


Fig. 25. Sidewalk Forms

During the summer, concrete needs moisture to harden or cure properly. For this reason, new concrete walks should be protected from drying out for about five days. Burlap, canvas, straw, or soil can be spread over the walk and sprinkled several times a day to keep it damp.

Flagstone Sidewalks. Suppose it is desired to build the flagstone walk between the porch and terrace in Fig. 20. From the approach walk to *T*, the cords are set up and the preliminary excavation carried on in the same manner as explained for building the approach walk.

Cords cannot be set up easily on the curves, so the following procedure is followed. Locate point *R* by means of the dimensions given. Drive a stake at that point. Then, with one person holding one end of a

Fig. 26. (Above) Using Wood Float to Finish Concrete Surface

(*Right*) A Groover Is Used to Mark Off Divisions in Concrete Walks

(*Below*) Using a Steel Trowel to Finish Concrete Surface

Courtesy of Portland Cement Association

measuring tape at stake *R,* a second person scratches the soil with a hatchet or trowel at various spots between *1* and *2,* as shown near the flagstone walk in Fig. 20, and between *3* and *4,* making certain by means of the tape that the scratches are all either 7′ 0″ (for one row) or 10′ 0″ from stake *R.*

Excavate the trenches, making their sides about 3″ on either side of the two lines of scratches. They should be approximately 5″ deep.

The forms for the curves should be thin pieces, approximately ½″ thick which can be bent easily as indicated in Fig. 27. Starting at *1* and *2,* drive two stakes so that the sides of the stakes next to the walk are 6′ 11½″ from *R.* Drive stakes *3* and *4* so that their sides next to the walk will be 10′ 0½″ from stake *R.* Drive other stakes at intervals of about 2′ on the 6′ 11½″ radius between points *1* and *2* and at the same interval on the 10′ 0½″ radius between *3* and *4.* Then the thin forms can be nailed, making sure their top edges are just at the grade level.

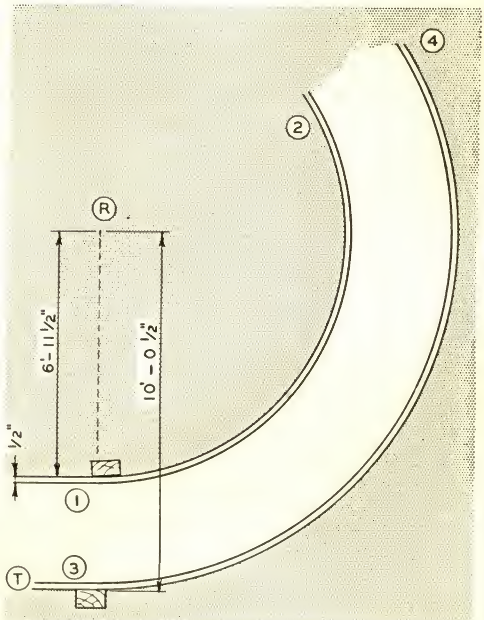


Fig. 27. Details of Curved Forms

Using the center marked *U,* the forms for the other curve in the walk can be erected in the same manner, then excavate and make the cinder fill as explained for the approach walk.

A mix of 1:2:4 concrete is used for the base and a mortar mix of 1:1 can be used for the joints between stones.

Using the base gauge, the concrete is leveled 2″ below the tops of the forms. Install the expansion joints for the base only at points marked *Z* in Fig. 20.

The forms can be used also as a guide for laying the flagstones. Select stones 2″ thick and trim their edges somewhat as shown in Fig. 9. Lay the stones on the concrete while it is still soft and work them solidly into place. The joints between stones should not be more than 2″ wide. Push the mortar solidly into the joints and smooth the surface with a small trowel.

Brick Sidewalks. To build brick sidewalks, prepare forms, make excavations, provide cinder fill, and pour concrete, etc., as explained for flagstone walks. Lay the bricks while the concrete base is still wet and fill the joints between them with cement mortar.

Driveways. Driveways are similar to sidewalks in that the same materials are used effectively in their construction. The most common of these is concrete and will be described first.

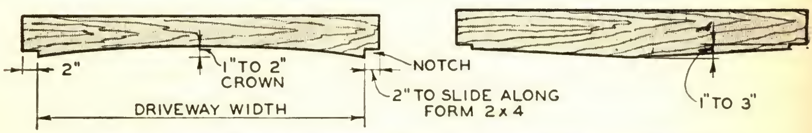


Fig. 28. Gauges for Leveling Concrete Base Course for Driveways

Concrete Driveways. Suppose it is desired to build the concrete driveway shown in Fig. 20. First drive a stake at point E and then one at point F. These two stakes should be 5′ from the property line. Stretch a cord between stakes E and F. Measure across 8′ 0″ from F and drive a stake at G. Measure across 8′ 0″ from the cord stretched between E and F and drive another stake at H. Stretch a cord between stakes H and G.

Carry out the preliminary excavation, setting of forms, final excavation, placing of cinder fill, and final check of forms as described for concrete sidewalks. Either 2 x 4 or 2 x 6 forms can be used. The expansion joint material is placed at points marked S in Fig. 20.

The concrete base is crowned or pitched to the center as shown in (A) and (B) of Fig. 5, by making gauges similar to those shown in Fig. 28.

The topping is placed as it was for sidewalks and is leveled with a gauge similar to the one shown in Fig. 28 except that no notches are provided. The finishing, joint marks, and curing are accomplished as explained for sidewalks.

FLAGSTONE AND BRICK DRIVEWAYS. Flagstone and brick driveways are built in the same manner described for flagstone and brick sidewalks except that they are crowned or pitched slightly as are concrete driveways.

Fig. 29 shows a simple but typical manner of making forms for curbs such as those illustrated in Fig. 12. Two-lane drives are made exactly like solid driveways except that more formwork is required.

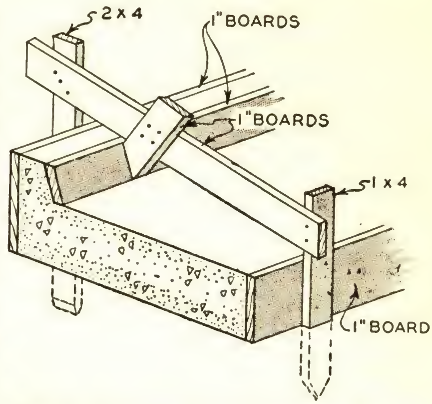


Fig. 29. Forms for Curbs Shown in Fig. 12

Floors. The importance of masonry floors has been stressed sufficiently. It is essential to bear this importance in mind when constructing these floors.

CONCRETE FLOORS. Suppose it is desired to lay a concrete floor in the one-car garage shown in Fig. 22. The floor sections *A, B, C,* and *D* must slope toward the drain. The concrete foundation for such a building is generally made so that its top is at grade level. The surface of the floor, therefore, should be flush with the foundation top. A plumber would set the drain at a level which would allow the correct slope in the floor.

The first step in laying the concrete floor will be the preparation of the ground so that it is a uniform depth. Unless the soil is very sandy, cinders will be required as a fill. This will call for an excavation 10″ in depth of which 6″ are for the cinder base. If excavation is necessary, the required amount of soil is removed and the bottom leveled by sight to the proper slope. The reverse process is used for filling in, soil being spread about until the bottom is the correct distance below the surface of the drain.

Next, place 2 x 4's from *F* to *G*, *F* to *H*, *F* to *J*, and *F* to *E* so that they rest on the soil. Place a level on each at the points marked with an *x*. The slope of the 2 x 4's thus can be checked. They should all slope the same amount toward *F*. More excavation or partial filling with cinders can be done as required to make all 2 x 4's slope the same amount from the foundation top to *F*.

Place the cinders over the floor in an approximately uniform depth, using the 2 x 4's as a guide. Remove the 2 x 4's and tamp the cinders. After tamping, replace the 2 x 4's, check the slope using a level, and add or take away cinders as is necessary to produce a uniform slope. The slope in the spaces between 2 x 4's can be judged by moving the 2 x 4's from side to side and checking with the level. Allow the 2 x 4's to remain in position as a guide for the thickness and the slope of the concrete.

Concrete of a 1:2¼:3 or 1:2:4 mix is used. Make the mix rather stiff so that it can be tamped firmly into place. Start placing concrete in the *GFH* section. Fill the section with concrete. Then, using a straightedge from the 2 x 4 at *GF* to the 2 x 4 at *FH*, check the thickness of the concrete by pulling the straightedge from *GH* toward *F*. Place and level concrete in the other three sections in the same manner. Then tamp firmly, taking care to check the level and slope again with the straight edge. When all concrete has been placed and the level checked, remove the 2 x 4's and fill the spaces they left with concrete.

Next, mix a topping of 1:1 or 1:2 cement mortar and place it over the concrete. The straight edge again can be used to spread the topping evenly following the contour of the concrete. Allow the topping to stand until it is stiff, then finish with wood float, steel trowel, etc. No joints are required. Before the driveway is poured, it is a good policy to put in an expansion joint between *K* and *L*.

Drains sometimes are not installed in garage floors. In such cases, the floor must slope from *GH* toward *EJ*. For this type of concrete floor, place the 2 x 4 guides in the positions of the dotted lines parallel to *GE* and *HJ* and use the level to establish and check the slope.

In summer, such concrete floors can be used within seven or eight days. In cold weather, they should not be used for at least two weeks.

Basement concrete floors are laid in much the same manner. Generally, such floors rest on footings. This is one way of establishing basement floor surface levels. Below that level will be 4″ of concrete and 6″ of cinders if the soil is not sandy. Or, a 2 x 4 can be cut to the required ceiling height (distance from surface of floor to underside of first floor joists) and that used to establish the floor level by moving it about from place to place. Around floor drains, the slope is established and checked as described in the description for the garage floor. Expansion joints

in basements should be placed around the floor at the junction of the floor and foundation. The same mix of concrete and topping can be used as given for garage floors. The finishing is the same as explained for concrete walks. No joints are required for basement floors. For large floors, a long float may be used as illustrated in Fig. 30.

Fig. 30. Use of Long Float to Remove Marks Left by Short Float
Courtesy of Portland Cement Association

CONCRETE BASE FLAGSTONE TERRACE. Suppose it is desired to construct the concrete base flagstone terrace shown in Fig. 20. This terrace is 12′ 0″ square and its top surface should be at grade line. Assume the residence already has been built.

The flagstones for terraces are generally various sizes of square and rectangular shapes. This can be noted in Fig. 20. Fig. 31 shows the details in a larger scale.

The first step is to lay out the terrace using stakes and cords. Fasten one end of a cord at A and have one person hold the other end near point D. A second person must hold a carpenter's square at A while the cord is moved until it lines up with the square and makes a 90° angle X with the side of the residence. Then drive a stake at D and fasten the cord to it. Next, measure 12′ from A and establish point H by a stake or nail driven into the foundation of the residence. Fasten one end of a cord at H, square it as previously described and tie it to a stake at E. Measure along cord AD a distance of 12′ from A

and make a chalk mark on the cord at B. Drive stake F opposite this point. Repeat the same operation along cord HE and drive stake G. Stretch a cord from stake F to stake G. The outline of the terrace is now established.

Under the cord, excavate trenches as explained for the walks and driveways. Then move the cords down to grade level and build and check forms using 2 x 4's also as explained for walks and driveways.

Excavate to a depth of 12″ to allow for 6″ of cinders, 4″ of concrete and 2″ of stone. Place the cinders, spread them evenly, and then tamp.

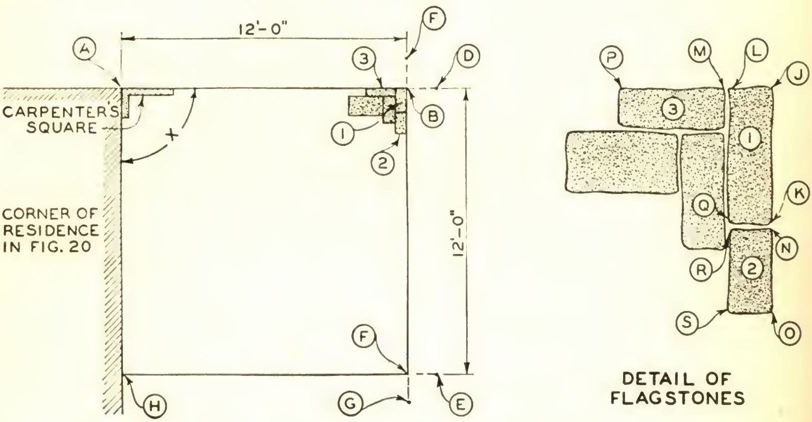


Fig. 31. Details of Terrace Construction

Use either 1:2¼:3 or 1:2:4 mix of stiff concrete. Pour the concrete and check proper depth and level with a gauge similar to the one shown in Fig. 25 except that the offset must be 2″ deep to allow for stone. Tamp the concrete thoroughly and start placing stone at once.

Note stone *1* in the stone detail in Fig. 31. Sides LJ and JK must be square and the edges plumb. The stone can be trimmed square and plumb using a chisel and hammer. Sides LQ and QK should be approximately square.

Place stone *1* first. Press it firmly so it beds nicely in the concrete. See that sides LJ and JK are up against the forms. Side NO of stone *2* also must be square. Sides NR and RS need only be approximately square. Place this stone next as shown in detail. It should be up against the form in order to form a straight line with stone *1*.

In like manner, place stone *3*. The edges of all stones along the forms must be square.

The balance of the stones are placed to form any pattern desired. The various stones can be shaped with a chisel and hammer to suit any pattern. Some masons prefer to trim, square, and lay out the stones elsewhere on the ground so that when the concrete has been poured at the site of the terrace the stones can be placed quickly in their proper positions.

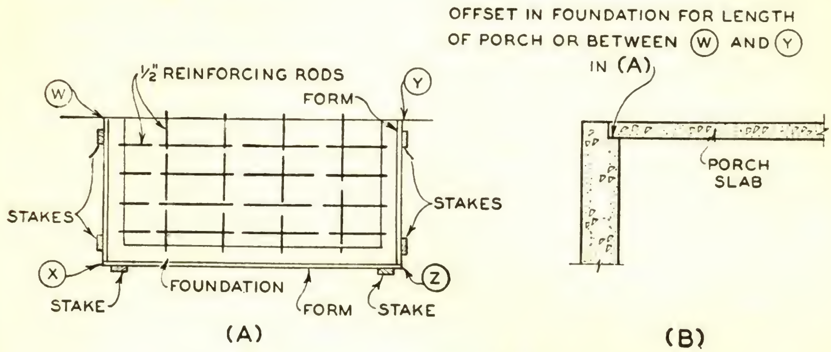


Fig. 32. Details of Concrete Porch in Fig. 20.

When all stones have been laid, a mix of 1:1 cement mortar should be packed firmly into the joints. Smooth the surfaces of the joints using a small trowel. In warm weather, the terrace can be used after six or seven days. The making of such terraces is not recommended during cold weather.

Concrete Porch. Suppose it is desired to make a concrete porch such as shown in Fig. 20, assuming that foundations or footings have been made with their tops at grade as shown in Fig. 21. Cut 2 x 4's for forms to lengths *WX*, *XZ*, and *ZY*, as shown in (A) of Fig. 32. Nail them at *X* and *Z*. Drive stakes as shown, so that the forms can be nailed to and held in place by them. If the soil is not up to the top of the foundation as shown in Fig. 21, fill in cinders and tamp thoroughly. If ½" steel rods are available, they can be placed in the same number and position as shown in (A) of Fig. 32. Remember that if rods are used, about 1½" of concrete should be poured before the rods are placed.

Either a 1:2¼:3 or a 1:2:4 mix of stiff concrete is used. Use a gauge to level the concrete to a depth of at least ¾″ below the tops of the forms. In order to obtain a smooth concrete next to the forms, mix some 1:1 concrete mortar and put it firmly against the forms all the way around. Tamp the poured concrete thoroughly.

Use a 1:1 mix of cement mortar for a topping. Finish as explained for sidewalks. Round the edges of the topping near the forms by using a curb edger. When the concrete is quite stiff, the forms can be removed and the sides troweled smoother with a steel trowel. The concrete, during warm weather, can be walked on after four or five days. This construction is not recommended at all during cold weather.

Offsets in foundations sometimes are made, as shown in (B) of Fig. 32, to help support the porch slab. This is good practice, helping to prevent cracking in the porch slab.

Dairy Barn Floors. Although Fig. 15 illustrates a typical dairy barn floor, a description of the building of this floor is not given here. Such a floor is an extremely complicated piece of work and should be done by or under the supervision of masons who have had a considerable amount of experience.

Steps. Suppose it is desired to build concrete stairs for an outside entrance to a basement which is about 3′ 5″ below grade as indicated in Fig. 16. As shown in the plan and section views, the walls on either side of the steps would be constructed at the same time as the foundation and in the same manner. The opening in the foundation for the basement door also would have been made as the foundations were poured, From these operations, a considerable amount of excavation already would have been done in order to have room to build the 8″ wall forms.

The 3′ 0″ by 4′ 0″ floor outside the basement door is made first using one form piece at the location marked X in the plan view. The two walls and the basement floor serve as the other forms. The concrete is poured over cinders or right on the soil and sloped toward the drain. Topping is applied in the usual manner, making sure that this floor is slightly below the basement floor as a means of preventing rain water from running into the basement.

Knowing the depth is 3′ 6″ and that the distance from the edge of the floor marked X to the end of the walls is 4′ 7″, it can be found by a

few trials that six 7″ risers and five 11″ treads will just equal the 3′ 6″ and 4′ 7″ dimensions.

The perspective section view in Fig. 16 shows clearly how the forms are made. Two 2 x 6 planks, one on each side, hold the forms in place. The risers are held in place by supports and braces nailed to the plank. The first 1″ thick riser form (at the bottom) is set at the edge of the floor and held in position by the supports nailed to the plank. The second riser is put into position 10″ behind the first one with its bottom edge level with the top edge of the first riser. (See the form detail in Fig. 16.) The other risers are placed in the same manner, excavating as may be required to allow for at least 3″ of concrete below each tread.

When the forms are complete, care should be taken to see that the widened base, shown at *A* in the perspective section view, is provided for. Forms for the sidewalk at grade should also be set so that the sidewalk and steps can be poured at the same time.

A stiff mix of either 1:2¼:3 or 1:2:4 concrete is used. Start placing the concrete at *A*. Before filling in the first step, apply 1″ or 1½″ of a 1:1 cement mortar to the inside of the riser form. This will make a smooth surface when the forms are removed. Then completely fill the first step to within 1″ of the top of the form. As the pouring of the second riser is started, put cement mortar along the inside of the form and force some down under the form, as at *B*. Continue the pouring in this manner.

Apply topping (1:1 mix) to the treads and finish as explained for sidewalks. When the topping has become quite stiff, the forms can be removed and a steel trowel used to further smooth the treads and especially the risers, and to make the corners between treads and risers sharp and distinct.

The steps should not be used until they have been allowed to harden for at least two weeks in order to prevent the breaking off of the edges where the toe of the foot strikes the tread.

Rear-Entrance Platform. Suppose it is desired to build a rear-entrance platform and steps such as that shown at (A) in Fig. 19, assuming that the foundations, (B) in Fig. 19, were made at the same time the main foundations were poured.

The first step is to fill the area between the foundations with soil

or cinders tamped down firmly. The platform is 21″ above grade which allows for three 7″ risers. The treads should be 11 inches. The forms are simply made, as shown at (C) in Fig. 19.

A stiff mix of 1:2:4 concrete is used. Start placing the concrete at the rear of the form next to the brick wall, being careful to place a layer about 1″ thick of 1:1 cement mortar against the forms to create a smooth surface next to the forms. Place concrete to within ¾″ to 1″ of the tops of platform and step forms. Then apply a 1:1 topping and smooth, using a wood float and steel trowel.

It is difficult to remove the forms before the concrete is hardened without the chance of removing them too soon. For this reason it is recommended that the forms be left in place for at least a week in warm weather. The steps and platform should not be subjected to heavy use for at least ten days.

Because of the cost of materials, some masons do not completely fill such forms with concrete. Instead, about 8″ of concrete is placed on each side as indicated in (B) of Fig. 19, and the center portion then filled to within 6″ or 8″ of the top with soil or cinders. This saves a considerable amount of concrete and is good practice if carefully done.

In Fig. 17, the forms shaping the sides of the steps have been cut to conform to treads and risers and to provide for curbs. Otherwise, the forms for these two flights of steps are not much different from those explained previously. Their construction is simple as shown in detail in the illustration. Concrete and topping is placed and finished as previously explained.

The forms for self-supporting reinforced concrete steps, illustrated in Fig. 18, are made following the same general plan as explained for Fig. 16 except that underforms also are required.

When building brick steps such as shown in Fig. 11, forms must be used for pouring the concrete bases just as for concrete steps. The bricks are laid on a bed of 1:1 cement mortar. The same mortar is used in the ¼″ joints between the bricks.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you

have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. Why it is necessary to use a steel trowel sparingly when finishing the surface of a concrete sidewalk?

Answer. Because an excessive amount of troweling causes the topping surface to crack and dust.

2. Why expansion joints are necessary for sidewalks, driveways, and floors?

Answer. To prevent cracking or buckling as the concrete expands during warm weather and contracts during cold.

3. When a cinder fill is necessary under sidewalks, driveways, and floors?

Answer. When the soil conditions are wet or when the soil is clay.

4. What the purpose of cinder fills is?

Answer. To allow accumulated water under the concrete to drain easily away from the concrete so as to prevent cracks, breakage, etc., which would result if such water froze before it had had a chance to drain off. If water freezes in cinder fills, no expansion or heaving takes place because the cinders are not closely compacted.

5. If the flagstones used in making a terrace may be of any shape and have irregular sides and edges?

Answer. They should be square and rectangular in shape and in random sizes, and the stones used at the edges of the terrace must have their sides and edges square.

6. How the joints between flagstones are finished?

Answer. They are finished with a strong cement mortar. The mortar should be shoved firmly into the joints and then smoothed at the surface with a small steel trowel.

7. How thick concrete steps generally are made?

Answer. Approximately 50 per cent greater than the riser height.

8. What the minimum tread width is for all outside brick steps?

Answer. Twelve inches.

9. What governs the height of risers when making the concrete bases for brick steps?

Answer. The manner in which the bricks are laid. If they are laid flat, the riser height must equal the thickness of two bricks, 1¼″ joint, and the mortar bed.

10. How the strength of a driveway or wide sidewalk can be increased?

Answer. By embedding a heavy wire mesh in the concrete.

11. How a concrete porch slab can be strengthened?

Answer. By using steel reinforcing rods in it.

12. Where expansion joints should be used in a concrete basement floor?

Answer. All around the floor where it meets the foundation.

13. What a base gauge is?

Answer. A tool used in leveling the concrete in a base course in a sidewalk, for example, and to provide the proper space for the topping.

14. What the purpose of a wood float is?

Answer. To do the preliminary smoothing or finishing on concrete sidewalks, floors, etc.

15. What the purpose of an edging tool is?

Answer. To round off the top edges of a sidewalk, for example, next to the forms.

16. When a crowned driveway is the best type to use?

Answer. When the driveway is laid in level soil without any natural slope. In such a condition water will run off to the sides of the driveway.

17. Where toe holds are used in connection with floors?

Answer. In dairy barns.

REVIEW QUESTIONS

1. Explain how smooth surfaces are provided for in concrete next to the forms in stairs.
2. Explain how to establish and maintain the proper slope when laying a concrete garage floor.
3. Where is an approach sidewalk used?
4. Explain how to lay out the curves when laying a curving flagstone walk.
5. What is the purpose of a **Y** in a driveway?
6. Explain how to make the joint in the topping over a sidewalk expansion joint.
7. Why is it a poor policy to lay concrete sidewalks over a narrow fill?
8. Explain how joints should be made in a sidewalk 18′ 0″ wide.
9. What advantage is there in laying the bricks of a brick sidewalk on a bed of sand?
10. Explain the purpose of sleepers in concrete floors.
11. How can a concrete floor be waterproofed?
12. What radius is used for manger curvature?
13. Explain how to make forms for a concrete stairs between two retaining walls.
14. How can some amount of concrete be saved in the building of rear entrance platforms and steps?
15. Explain how to build the forms for a concrete sidewalk.
16. Explain how to determine the width for a proposed sidewalk.

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48 cu in.

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3000
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